Journal of Chemical Education

BOSTON UNIVERSITY
COLLEGE OF LIBERAL ARTS

Published by

Division of Chemical Education of The American Chemical Society

Easton, Pa.

Entered as Second-class Matter, January 31, 1924, at the Post Office at Easton, Pa., under the act of March 3, 1859. Accepted for mailing, at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized January 31, 1924.

Copyright, 1928, by Division of Chemical Education, American Chemical Society

Vol. V **September, 1928** **No. 9**

CONTENTS

	Page
Frontispiece	1038
Editor's Outlook	1039
Optical Experiments with Electrons. Part I. L. H. Germer	1041
The Relation of Chemistry to Health and Disease. Paul Miceli	1056
The Relation of Chemistry to the Enrichment of Life. Ruth Leslie	1062
The Relation of Chemistry to Agriculture. John B. Rae	1068
Chemistry in Relation to National Defense. Edward Gregg	1074
The Relation of Chemistry to the Home. Sylvia Simon	1079
Chemistry as Applied to the Oil Flotation of Copper Ores. Esther Laine	1084
Alfred Werner. Paul Pfeiffer	1090
Quantitative Organic Microanalysis. Ralph T. K. Cornwell	1099
The Value of the Lecture-Table Demonstration in the Teaching of Chemistry. L. A. Wiles	1109
Chemistry Projects in High School. J. E. Mahannah	1112
Charles Frederick Mabery, a Pioneer. W. R. Veazey	1117
A Conductivity Apparatus. Jesse E. Day and Ford C. Davis	1121
Modern Chemistry in Medicine. Sidney S. Negus	1123
Chemical Education at the University of Vienna. John S. Reese, IV	1124
The Combining Ratio of Copper and Sulfur. An Experiment for High Schools. Charles H. Stone	1129
A Self-Adjusting Buret Apparatus. Robert C. Hockett	1131
An Experiment in Coöperative Teaching. Wm. Lloyd Evans and Jesse E. Day	1133
The Nature of Matter. Phoebe Arnold Paine	1135
The Chemistry Student:	
Why Study Chemistry?	1148
The Structure of Matter. I. Hydrogen and Oxygen	1152
Water and Its Components	1163
Water Crystals. Pressure and Freezing. Pressure and Boiling. "Dry" Steam. "Water, Water Everywhere." Commercial Production and Uses of Hydrogen and Oxygen	
The A. C. S. Prize Essay Contests	1169
Bibliography for Prize-Essay Contestants	1172
Student Contributions	1178

Chemical Digest:

Photography 1179

Abstracts 1184

Teaching Methods, Aids, Apparatus, and Suggestions: A Buret Cleaner. An Automatic Mercury Cleaner. A Beaker Rack for Decantation. A Cork and Stopper Board. Files as Glass Knives. Cover Supports for Beakers and Dishes. A New Watch Glass. A Simple, Efficient Hydrogen Sulfide Generator. Solvent Economy in Extraction Work. A Non-Spattering Semi-Automatic Wash Bottle. Automatic Wash Bottle. A Convenient Wash Bottle. The Dripless Wash Bottle. A Glass Stopper Remover. Insertion of Tight-Fitting Glass Tubing into Rubber Stoppers. An Improvised Photomicrographic Apparatus. The Boiling Point and the Latent Heat of Vaporization of Water. Tenth-Normal Sodium Hydroxide. A Rapid Method for the Detection of Zinc in the Presence of Iron. Oxidation and Precipitation of Ferrous Compounds by Sodium Peroxide. Preparation and Standardization of Potassium Permanganate Solutions. The Rapid Analysis of Mixtures of Barium and Calcium Salts. Sources of Free Material for Science Instruction. The Use of Charts in the Natural Sciences. **Educational Measurements and Data:** Science in the New Curriculum. Scales for Rating Pupils' Answers to Nine Types of Thought Questions in General Science. Objective Measurements in General Science. An Analysis of Textbooks in General Science. **Keeping Up with Chemistry:** The Identification of Bios I as Inactive Inosite. The Radioactive Elements. Our Search for Chlorophyl and for the Vitamins. Hemoglobin. Temperatures. Silicates as Medicinals. The By-Product Fish Industry in Canada. Edgar Fahs Smith. Sir Isaac Newton on Gravitation. **The Philosophy of Science:** The Fun of Being a Scientist. **The Methods and Philosophy of Education:** College Entrance Requirements. Unity of Research. Research and the Training of the Researcher. The Place of Science in Education. **The Teaching Profession:** Teacher Participation in Curriculum Research. Suggestive Attributes of the Successful Teacher. Sound Retirement. Headquarters Retirement System. More Teachers than Jobs. A Method of Training Teachers in Service, the Dalton Laboratory Plan. **Miscellaneous:** Research Plus News-Gathering. Counting Molecules.

Local Activities and Opportunities 1193

Recent Books 1199

NOTICE TO AUTHORS OF PAPERS

1. Forwarding Address. Papers intended for publication in THIS JOURNAL should be submitted to Neil E. Gordon, Editor, The Johns Hopkins University, Baltimore, Maryland.

2. Manuscript. The manuscript submitted should be an original (not a carbon) copy, and typewritten, double-spaced, with 2–3 cm. margins. The title of the article should be followed by the name and address of the author. If the paper has been presented at a meeting, a footnote giving name of society, date, and occasion should immediately follow the author's name. The usual editorial customs, as exemplified in the most recent issues of the JOURNAL, should be followed as closely as possible.

3. References and Footnotes. Each reference to the literature and each footnote should be inserted without a number, as a separate line (or lines) immediately following the word to which it refers in the text. A reference to literature should include, in the order named, the title of book or article, author's name, edition or volume, pages, date of publication, and, in the case of books, publisher's name.

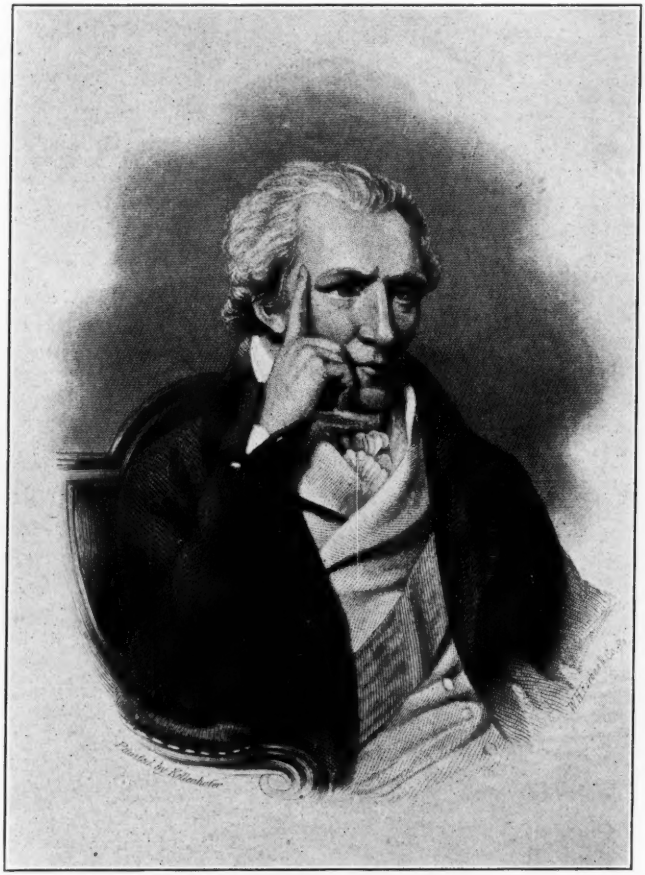
4. Illustrations. Not all articles lend themselves to illustrations, but articles which do should be accompanied by as many pertinent illustrations as possible. As a rule, apparatus, particularly if complicated, is best presented by means of line or working drawings. Photographs are sometimes sufficient, however. When both can be obtained, it is generally desirable to include both.

Photographs should have a gloss finish and should be at least post-card size—larger, if possible. Only prints which are unblurred and which show sharp contrast between light and dark areas can be satisfactorily reproduced.

Line drawings should be carefully prepared on plain white drawing paper or blue drawing cloth, twice or three times the size desired in the printed cut; it is convenient, when permitted by the scale required, to have them the size of the manuscript. When coördinate paper is used, it should be printed in blue only, with the important coördinate lines ruled over in black; the black square should in general not be less than ten millimeters on a side; the lines of the curves should be the heaviest, except the frame; points on the curves should be indicated by true circles, not crosses. The numbering of the coördinate axes, the number of the figure and any necessary explanations of the figure should be written in pencil in the margin of the sheet, as they are usually set up in type rather than reproduced from the drawing. All lines, numbers, and letters that are to be reproduced are to be so proportioned that they will be clearly legible in the cut.

Tables should be inserted in the body of the manuscript at the proper place.

All photographs, line drawings, and tables should be provided with self-explanatory titles or legends. Each illustration should be marked in pencil on the margin with the name of the author and the title of the article to which it refers.



PORTRAIT OF COUNT RUMFORD WHEN SENT TO ENGLAND AS AMBASSADOR FROM BAVARIA. 1798. AGED 45.

EDITOR'S OUTLOOK

THE amazingly versatile and original natural philosopher who has gone down in history as Count Rumford was born at North Woburn, Massachusetts, on March 26, 1753. Benjamin Thompson, for so the future Count Rumford began life, displayed, even as a schoolboy, a marked fondness for mathematics, the sciences, and for mechanical matters. His formal schooling must have been brief, for we are told that he was apprenticed to an importer at Salem at the age of thirteen. However, his education continued—partly through reading and experimentation undertaken on his own initiative and partly through the tuition of others. It later included attendance at lectures on experimental physics at Harvard. Upon his election to the Royal Society years later, he was described as "a gentleman well versed in natural knowledge and many branches of polite learning."

Count Rumford

The story of his life reads like a romance, but, although Fortune often smiled upon him, he demonstrated himself entirely worthy of her favors and his fame rests upon the substantial foundation of his own achievements. Upon the occasion of the 175th anniversary of Count Rumford's birth, Dr. Lyman C. Newell delivered at Woburn, Massachusetts, an address which outlined the career and accomplishments of the famous scientist. That address has been published under the title, "Count Rumford—Scientist and Philanthropist," in the July 27 number of *Science*.

The dedicatory tablet in Rumford Hall of the Chemists' Club, New York City, denominates Rumford "the first great chemist of American birth" and summarizes some of his more important activities as follows:

> By the discovery of the transformation of mechanical force into heat, he laid the foundation for the theory of the conservation of energy. His studies in the economy of fuel consumption represent the first conscious effort toward the conservation of natural resources. He was a pioneer in steam-heating and domestic sanitation. He was a pathfinder in constructive charity. Driven hence, as was Priestley hither, by neighborly intolerance, he became a dweller in many lands and a benefactor to each. Bavaria owed him an administration of unprecedented efficiency and a military system based on the manhood of the private soldier. To England he gave the Royal Institution, the home of Humphry Davy and of Michael Faraday. At Harvard College he founded the chair made famous by Eben Horsford and Wolcott Gibbs. America received at his hands its first endowment for the encouragement of research in the exact sciences.

It may be of interest to note that Count Rumford's second wife was the widow of Lavoisier, the French chemist. This union was not entirely happy, because of the divergency in the tastes and interests of the contracting parties.

We are indebted to Dr. Newell for the portrait reproduced as the fron-

tispiece of this number and for the photograph of the birthplace of Count Rumford which appears on page 1178.

Pandemic Chemistry and the Prize Essays

AS THIS copy goes to press the round-table discussion on "pandemic" chemistry arranged by the Division of Chemical Education for the seventy-sixth meeting of the American Chemical Society is still in prospect. Hence we are without benefit of such counsel as may be forthcoming there. Nevertheless it seems to us that, although the "pandemic" attitude in the teaching of chemistry must number among its opponents some thoughtful and excellent teachers, and among its adherents some misguided extremists, it is not without considerable merit.

We must face the fact that our standard instruction in elementary or general chemistry is an outgrowth of the apprentice system. It may reasonably be expected to give good results in the training of chemists. If it also serves satisfactorily as a cultural course for those who do not pursue the study of science farther, that is a happy coincidence—a lucky shot which, aimed at one bird, brings down two. Conditions have changed since chemistry was first introduced into the general curriculum. We have a different class of students with which to deal, and we are beginning to acquire a more extensive knowledge of the learning process with a consequent skepticism concerning multiple-purpose operations. *Have* we, in fact, been consistently winging two birds at a shot, or has the wish been father to the thought?

But it was not our purpose to discuss here the pros and cons of the "pandemic" chemistry issue. We desired only to suggest to those who see some good in the "pandemic" method of attack, but who nevertheless prefer to proceed conservatively, that the A. C. S. prize essay contest offers an excellent opportunity to wade into deep water gradually. The essay provides the teacher with a means of motivation for the type of student reading which he quite properly hesitates to substitute for the more orthodox chemistry and which it is almost impossible to demand in addition to regular course work. It is now none too early to begin to employ it. For the rules of the contest and further discussion see "The Chemistry Student" section, page 1169.

OPTICAL EXPERIMENTS WITH ELECTRONS. PART I

L. H. GERMER, BELL TELEPHONE LABORATORIES, NEW YORK CITY

The title of this paper may sound paradoxical. Almost everyone knows that electrons are discrete units of electricity; they are the indivisible particles of which atoms are made. How then can optical experiments be performed with them?

In spite of all this it must be emphasized that the experiments with electrons which are to be described here are *really optical experiments*. In no sense are the phenomena which Dr. Davisson and I have observed to be thought of as only vaguely resembling optical phenomena. The experiments which we have performed are actually optical experiments with electrons, just as certainly as experiments with x-rays are optical experiments. The technic of x-ray experimentation is, of course, quite different from the technic of experimentation with visible light. The technic of our experiments with electrons is also quite different from the technic of ordinary optics. This difference is, however, a difference in experimental convenience rather than a difference in principle. Our experiments establish the wave nature of moving electrons with the same certainty as the wave nature of x-rays has been established.

In the experiments which are to be described here electron wave-lengths are determined by diffraction measurements using a crystal of nickel as diffracting lattice. Our most careful wave-length determinations possess an accuracy which is almost comparable with the accuracy of the best determinations of the lattice constant of nickel. The wave-lengths of readily obtainable electrons are in the x-ray region; that is, these wave-lengths are comparable with the distances between atoms in solid bodies. For this reason, in the experiments which we have performed, *diffraction phenomena have been predominant.* But, as is implied by the title of this paper, in addition to diffraction we have observed other optical phenomena. We have observed reflection and refraction. We have established the dispersion curve for nickel and have observed a phenomenon which is suggestive of optical anomalous dispersion.

. . . . . .

These remarks may have been rather premature. The experiments leading up to the discovery of the wave nature of moving electrons had their beginning in the year 1920. At that time Dr. C. H. Kunsman was working under the direction of Dr. C. J. Davisson in the laboratory of the Western Electric Company upon the number of electrons emitted by a metal surface when the surface is subjected to the bombardment of ionized gas molecules. Without changing the experimental apparatus used for the bombardment by positive ions, Davisson and Kunsman were able to make

measurements upon the secondary electrons arising from the bombardment of the target by primary electrons. Among these secondary electrons they discovered some leaving the metal surface with speeds about the same as the speeds of the primaries. Such full-speed secondary electrons had been observed before for primary electrons having speeds corresponding to voltages up to about 12 volts. For faster primary electrons these full-speed secondaries had not been heretofore observed.

It seemed probable to Dr. Davisson that these high-speed secondary electrons must be some of the original primary electrons which, in the electric fields surrounding the nuclei of atoms, had suffered large angular deflections without loss of energy. If this hypothesis were true, this scattering of electrons ought to offer a means of probing into the atoms within which the electron scattering must take place. It should give information about the fields of force within the atoms in much the same way that such information was obtained by Rutherford from the scattering of alpha particles. Because of the small energy of the scattered electrons this information would concern the outer part of the atom—a region about which no information is obtainable from α-ray scattering.

After 1920 these scattering experiments were vigorously prosecuted by Davisson and Kunsman for several years. During the last four years I have assisted Dr. Davisson in this experiment of electron scattering. Up to date the amount of information which we have obtained regarding the force fields within atoms has been rather meager. Contrary to the anticipated course of the experiment, we have obtained very interesting information regarding the nature of the bombarding electron itself rather than regarding the atoms which are under bombardment.

In describing the electron scattering experiments I am not going to follow the development chronologically. Some of the most recent work can best be mixed in with the earlier measurements. In the following pages the attempt has been made to start in with the simplest type of measurement and to make the entire presentation as clear as possible.

The Reflection of Electrons[1]

For the last few months we have been engaged in an extremely simple type of experiment. We direct a narrow stream of electrons against the face of a nickel crystal, and observe that under certain conditions a sharply defined stream of electrons leaves the crystal in the direction of regular reflection—angle of reflection equal to angle of incidence.

At first thought there may seem to be nothing so very strange in this.

[1] This section and part of the following section of this paper are taken largely from an address delivered by Dr. Davisson before the Franklin Institute of the State of Pennsylvania on March 21, 1928, and published in the *Journal of the Franklin Institute*, **205, 597** (May, 1928).

Why should not electrons be regularly reflected from a metal surface? We recall that the adherents of the corpuscular theory of light were not embarrassed by the fact that light is regularly reflected from a plane mirror. The phenomenon is one that they could explain quite easily. It is well known that in an elastic encounter between a particle and a plane surface the particle rebounds from the surface in the direction of regular reflection—hence the regular reflections of light on the corpuscular theory, and why not also the regular reflection of electrons?

The difficulty is that we know too much about the structure of metallic surfaces and about the size of the electron. We know that atoms have diameters of the order 10^{-8} cm. and that the diameter of the electron is about 10^{-13} cm. If we take 10^{-13} cm. as a unit of length, then the diameter of the electron is one of these units, the diameter of the nickel atom is one hundred thousand units, and the least distance between atoms in the nickel crystal is nearly 250,000 units.

The difficulty of picturing the regular reflection of particles as small as electrons from a surface made up of bodies as large as atoms is evident. It is like imagining a handful of bird shot being regularly reflected by a pile of large cannon balls. A surface made up of cannon balls is much too coarse-grained to serve as a regular reflector for particles as small as bird shot.

The analogy is not such a good one really, for we do not think of electrons rebounding from the surface of an atom in the way that shot rebound from a cannon ball. We have been accustomed to think of the atom as rather like the solar system—a massive nuclear sun surrounded by planetary electrons moving in orbits about it. On this view the electron which strikes into a metal surface is like a comet plunging into a region rather densely packed with solar systems.

There would seem to be a certain small probability that the electron will strike into an atom in or near the surface of the metal—be swung about comet-wise, and sent flying out of the metal without loss of energy. This was the interpretation of the scattering phenomenon which Dr. Davisson had in mind when the scattered electrons were first discovered. The direction taken by one of these electrons as it leaves the metal should be a matter determined solely by the individual atom. One does not see how the neighboring atoms could have anything to do with it. And yet we find that the high-speed scattered electrons have a preference for moving off in the direction of regular reflection, a direction which is related to the plane of the surface. At least three atoms are required to fix this plane, so that the direction taken by the electron is determined not by one atom, but at the very least by three atoms.

One may say without qualification that in terms of atoms and electrons, and their interaction as we have been accustomed to picture them, the

regular reflection of electrons from a metal surface is quite incomprehensible. As a matter of fact in our earlier experiments, in which we were bombarding a block of polycrystalline metal, we never observed regular reflection under any circumstances. Regular reflection was observed only when we were using a single metallic crystal and when the surface was cut to an important crystallographic plane. In other words, regular reflection occurs only from an important plane of atoms in a crystal.

The result of this very simple experiment is surely suggestive of the reflection of waves. The fact that reflection does not occur from a polished surface, but only from a crystallographic plane, is suggestive, furthermore, that the wave-length to be attributed to these hypothetical waves is not long in comparison with the dimensions of the crystalline structure. If the wave-length were long in comparison with the dimensions of the

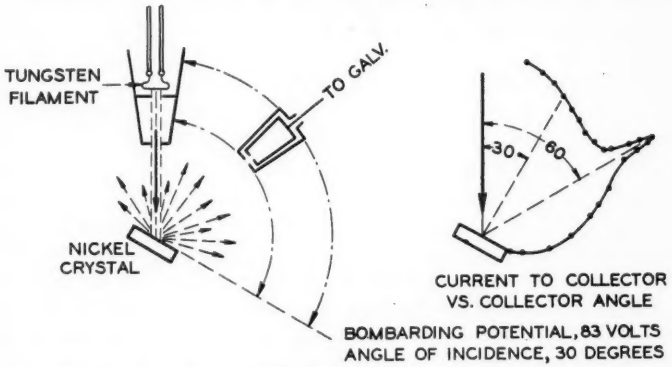


FIGURE 1.—Schematic representation of the apparatus used for finding the reflection of electrons by a crystal, and a typical curve showing regular reflection of electrons.

structure, reflection would of course occur from a mirror surface as well as from a crystallographic plane.

A schematic diagram of the experimental arrangement is shown on the left in Figure 1. This arrangement of filament and box is an "electron gun" which supplies us with a steady stream of electrons. The speed of the electrons is under our control and can be given any desired value by maintaining a suitable potential difference between the filament and the box. This stream is directed against the crystal, and electrons of various speeds move off in all directions from the bombarded area.

To find how many are moving off in different directions we move the collector about and find how many electrons we catch in different positions. To get into the inner box of this collector an electron must pass through the opening in the outer box. Those that succeed in doing this flow off

through a galvanometer, and the deflection of the galvanometer is a measure of the rate at which they are being caught.

In making observations the collector is moved about in front of the crystal, and curves are constructed showing the current received by the collector as a function of angle.

Such a curve for angle of incidence 30 degrees and for bombarding potential 83 volts is shown on the right of Figure 1. The sharp spur protrudes from the curve exactly in the direction of regular reflection. Most of the electrons making up this spur are full-speed scattered electrons, electrons which have lost none of their initial energy on being scattered by the crystal. Outside of this spur over ninety per cent of the electrons making up this curve are low-speed secondary electrons. If we were able to stop off these low-speed electrons, as we could in some of the experiments which will be described later, nothing would be observed except the beam of reflected electrons.

There is no doubt that the incident electrons recognize the surface of the crystal, and prefer to move off in the direction of regular reflection. And this does not occur except when the surface is a definite crystallographic plane.

Unless electrons are waves it seems curious that they should be reflected only from a crystal-face. Of course we know that x-rays may be regularly reflected from the face of a crystal, but not from a polycrystalline mirror. As suggested a moment ago, the difference between light and x-rays in this respect is due to a difference in the size of the wave-length. The wave-lengths of light waves are great compared to the distances between atoms in solids while the x-ray wave-lengths are comparable with these distances.

To recapitulate, both of these results—the regular reflection of electrons from a crystal-face, and the absence of such reflections from a polycrystalline surface—indicate that electrons are trains of waves of wave-lengths comparable with distances between atoms in solids.

Now it will be remembered that x-ray reflection is characterized by a marked selectivity. If a beam of mono-chromatic x-rays is directed against a crystal face, the intensity of the reflected beam is very nearly zero unless the wave-length of the beam happens to lie at or very near to one or another of series of discrete values.

This suggests an interesting experiment. If electrons resemble x-rays in being reflected from a crystal, but not from a polycrystalline surface, do they also resemble x-rays in exhibiting selective reflection? We might expect, for example, if electron reflection is really like x-ray reflection that it would be selective in speed of bombardment. Well, the fact is that it *is* selective in speed. When we measure the intensity of the reflected beam as a function of speed of bombardment we find that it passes through one

maximum after another as the speed is increased. A curve exhibiting this behavior is shown on the right in Figure 2.

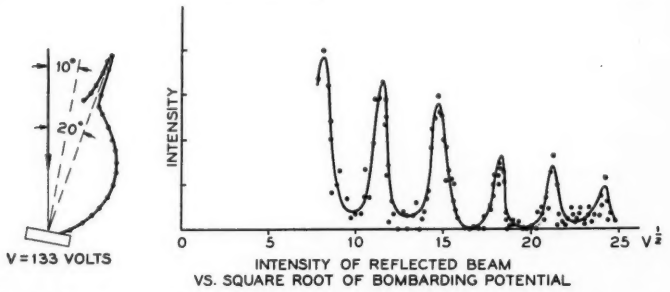
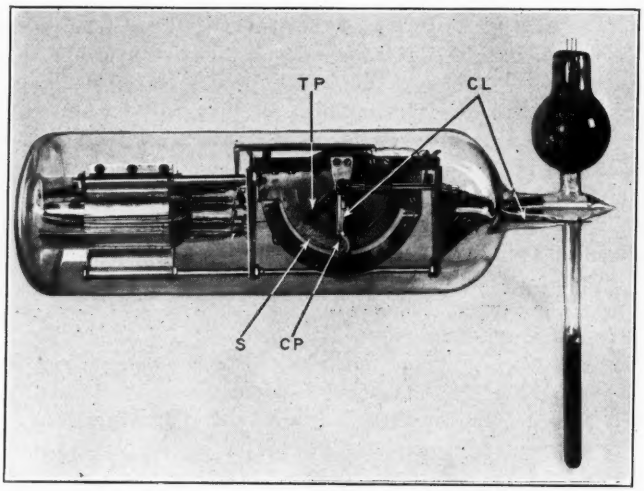


FIGURE 2.—Showing the selectivity of the reflection of electrons incident at 10° upon a nickel crystal.

The ordinate of this plot is the intensity of the reflected beam, and the abscissa is the square root of the bombarding potential, which is proportional to the electron speed. These observations are for



PHOTOGRAPH OF THE APPARATUS USED IN MEASUREMENTS UPON THE REFLECTION OF ELECTRONS

The angular positions of the target and collector are given respectively by the readings of the target pointer *TP* and the collector pointer *CP* upon the scale *S*. The collector lead wire is indicated by *CL*.

an angle of incidence of ten degrees. The curve on the left in Figure 2 shows the reflected beam at the second maximum of the intensity curve.

Now the selective reflection of x-rays is of course a phenomenon which is very thoroughly understood. In explaining it we make very definite and explicit use of the idea that x-rays are waves. In fact, the phenomenon supplies us with our most reliable means of measuring x-ray wave-lengths. It is very significant indeed that electron reflection resembles x-ray reflection in this particular respect.

If we could observe x-ray reflection from a single layer of atoms it would be found that it is not selective. Selectivity develops when reflection occurs from a number of parallel layers of atoms such as we have in a crystal. We reason, from analogy with x-rays, that the selectivity of electron reflection implies that our electron waves, which of course are still only hypothetical, are reflected from more than one layer of atoms—that is,

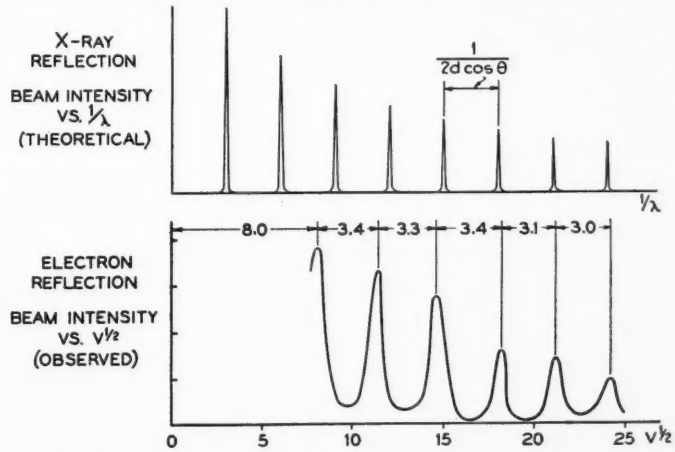


FIGURE 3.—Comparison of the selectivity of x-ray reflection and the selectivity of electron reflection.

that they penetrate considerably into the surface of the crystal. At the same time the considerable breadths of the peaks on this curve showing the selectivity of the reflection implies that the penetration is only moderate. The selectivity is not so sharp as in the case of x-rays.

The condition that the selective reflection of x-rays shall occur is given by the Bragg formula, $n\lambda = 2d \cos \Theta$, where λ is the x-ray wave-length, n an integer, d is the separation between the parallel layers of atoms, and Θ the angle of incidence upon the plane of one of these layers. The Bragg formula may be written: $\frac{1}{\lambda} = n \frac{1}{2d \cos \Theta}$.

Thus, if we plot the intensity of the reflected beam against the reciprocal of the wave-length, we should obtain a curve characterized by a series of

equally spaced maxima corresponding to various values of the integer n. What we should find is illustrated by the curve at the top of Figure 3.

In the lower half of this figure is shown again, for comparison, the intensity of the reflected electron beam as a function of $V^{1/2}$, the square root of the bombarding potential.

The maxima in the electron curve fall at almost equal intervals. We may say, in fact, that we could understand electron reflection fairly well, including its selectivity, if electrons were waves of wave-length inversely proportional to the square root of the bombarding potential—inversely proportional, that is, to their speed. Even what the proportionality factor is, which connects wave-length and the reciprocal of electron speed, can be discovered approximately by fitting together the two curves of this figure. Apparently this would not do exactly, as the maxima of the electron selectivity curve do not fall at exactly equal intervals. Although this assignment of wave-lengths to our hypothetical electron waves could do fairly well, it seems that some important factor has been neglected.

The Diffraction Experiment—Establishing the Wave Nature of the Electron

Thus far there have been shown only the results of what would appear to be the very simplest type of experiment which can be performed. The attempt has been made to push the implications of this experiment as far as possible before going over to a more effective means of carrying on the investigation.

Leaving for a few moments the apparent similarities between the behavior of electrons and the behavior of x-rays, let us consider the diffraction of visible light. Everyone knows that, in determining the wave-length of light by means of an optical grating, we do not make measurements upon the central image—that is, the regularly reflected beam. Measurements are made upon a diffraction beam lying on one side of the central image. In our nickel crystal we can consider rows of atoms making up the surface layer of atoms as forming a plane diffraction grating, and the question at once arises whether or not we can observe coming from the surface of our crystal other electron beams in addition to the regularly reflected beam—or the "zero order" beam. Such beams have been found, and from the positions of these beams we have actually calculated electron wave-lengths just exactly as light wave-lengths are calculated from the positions of diffraction beams arising from an optical grating. In the apparatus used for the reflection experiments—the apparatus shown schematically on the left in Figure 1—we were able to find first and second order diffraction beams, and our most precise wave-length determinations were made with this apparatus.

It happens that in the apparatus which was best adapted to the obser-

vation of diffraction beams, other than the zero order, we were bombarding the surface of our crystal normally. The regularly reflected beam, or the diffraction beam of zero order, came straight back and was outside the region of observation. In this experiment, which is about to be described, we were limited to first, second, and third order diffraction beams from the surface of the crystal. This was the first type of experimental apparatus and these various diffraction beams were observed before we were able to discover the beams showing regular reflection.

Although the consideration of these diffraction beams is almost as simple as the consideration of the reflection beams, it will be convenient to understand a little more about the structure of the diffracting crystal. The unit of structure is a cube—3.51 Angstrom units on the edge—with an atom at each corner and one in the center of each face. The large cube on the left in Figure 4 is built up of 27 of these unit cubes. The only atoms shown are those in the surface of the large cube. It will be convenient to use this large cube occasionally as a symbol to represent the nickel crystal with which we began our experiments.

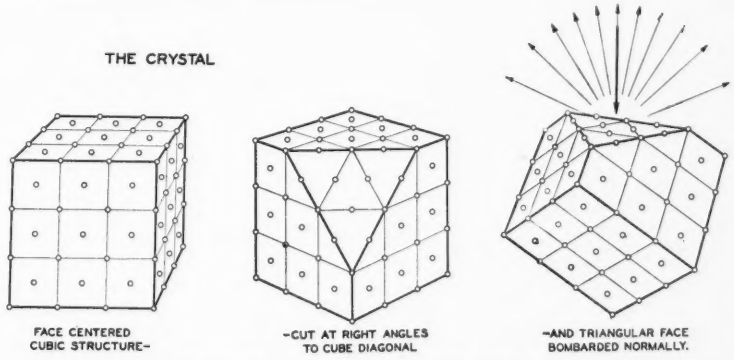

THE CRYSTAL
FACE CENTERED CUBIC STRUCTURE–
–CUT AT RIGHT ANGLES TO CUBE DIAGONAL
–AND TRIANGULAR FACE BOMBARDED NORMALLY.

FIGURE 4.—Schematic views of the face-centered cubic crystal of nickel.

In this early experiment which I am about to describe we first cut through this structure at right angles to one of the cube diagonals forming the triangular face shown in the center of Figure 4. In x-ray notation this is a (111) face. A beam of electrons was then directed against this face at normal incidence, as indicated in the figure on the right, and measurements were made of the number of electrons leaving the crystal as a function of direction and of speed of bombardment.

The experimental arrangements for making these measurements are indicated in Figure 5. The collector could be moved about in a single plane—the plane of the drawing—and the crystal could be rotated about a

vertical axis so that any azimuth of the crystal could be brought into the plane of rotation of the collector.

It is clear that the crystal has a three-fold symmetry, because of the way in which it has been cut. If we find a beam of electrons issuing from the crystal when one of the apexes of the triangle is in the plane of the collector we shall expect, of course, to find a similar beam when the crystal has been turned through 120 degrees to bring another of the apexes into the collector plane, and again when it has been turned through 240 degrees. This three-fold symmetry was always found in the electron scattering patterns. I shall call the azimuths of the crystal that include the apexes of the triangle the *A*-azimuths, those including the midpoints of the sides of the triangle the *B*-azimuths, and those parallel to the sides of the triangle the

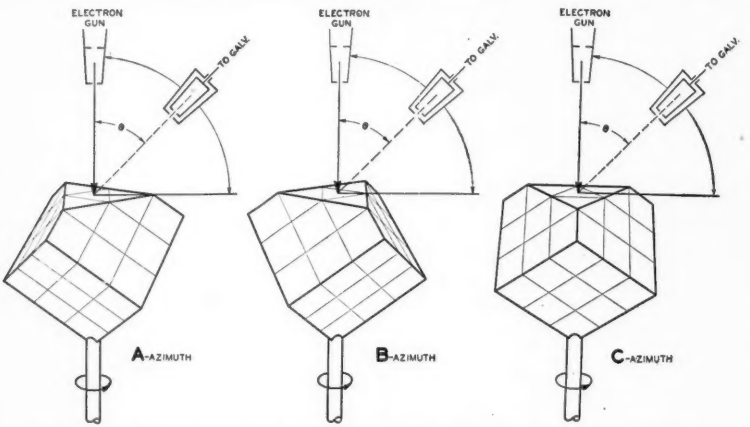


FIGURE 5.—The experimental arrangement for investigating electron diffraction.

C-azimuths. This designation of azimuths is for convenience in describing the phenomena and need not be remembered.

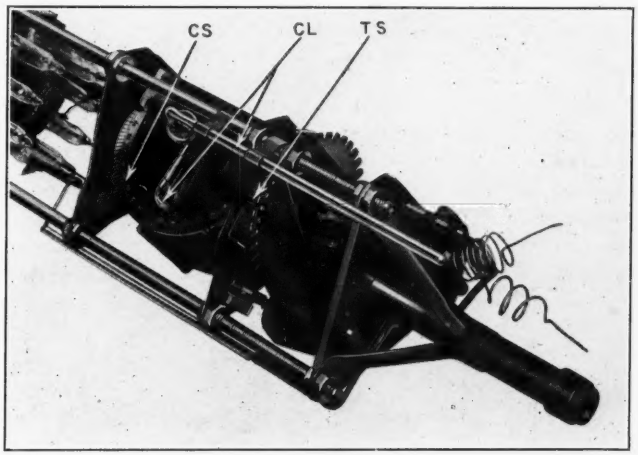
This type of apparatus is somewhat more flexible than the reflection apparatus and the measurements required are a little more extended. Actual measurements were made by setting the crystal so that one of its principal azimuths coincided with the plane in which the collecting electrode moves about, and then exploring about for all different speeds of the electrons striking the crystal. An exhaustive exploration was made, both in angle and voltage, for each of the principal crystal azimuths.

. . . . . .

Now consider the phenomena observed when light of adjustable wave-length is incident normally upon a plane grating. As the wave-length is steadily decreased from a rather large value, the first order diffraction

beam occurs just grazing the surface at a critical wave-length equal to the grating space. As the wave-length is decreased this first order beam moves uniformly up from the surface with no marked change of intensity. The position of the beam and the wave-length of the light are related by the equation $\lambda = D \sin \Theta$, where D is the distance between adjacent grating lines and λ is the angle between the beam and the normal to the grating.

This optical behavior is closely paralleled by the behavior of the electron-scattering pattern as the potential of the bombarding electrons is increased from a small value. At a critical potential of 32.5 volts sharply defined beams of electrons emerge from the crystal just grazing the surface, simultaneously in the A- and B-azimuths. With increasing potential these



PHOTOGRAPH OF THE ELECTRON DIFFRACTION APPARATUS

Scales *TS* and *CS* show respectively the azimuth of the target and the angular position of the collector. The collector lead wire is marked *CL*.

beams move steadily up from the surface, as does an optical diffraction beam as wave-length is decreased. Selectivity soon develops and these beams go through maxima and minima, just as did the regularly reflected electron beam as bombarding potential was changed. As in the case of electron reflection, one must infer from this selectivity that the penetration is considerable, except for the beams near to grazing emergence.

In Figure 6 is shown the arrangement of atoms on the surface of this nickel crystal. We have considered the lines of atoms on the surface as forming plane gratings. The grating spacing is 2.15 Angstrom units in the A- and B-azimuths and 1.24 Angstrom units in the C-azimuths. The electron beams which come from the surface just at grazing in the A- and B-

azimuths must have a wave-length equal to the grating spacing—that is, 2.15 A. As the potential of these beams is 32.5 volts we shall conclude that a 32.5-volt electron has a wave-length of 2.15 A.

Now when the potential has been raised to 97.5 volts sharp electron beams appear grazing the surface in the *C*-azimuths, and as the potential is raised still further these beams move steadily up from the surface. Their intensities soon begin to show a marked selective effect, just as happened in the other azimuths. As the grating constant in the *C*-azimuth is 1.24 A., we are to conclude that a 97.5-volt electron has a wave-length of 1.24 A.

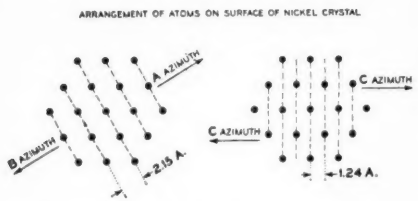


FIGURE 6

At a considerable distance above the surface the selective effect becomes very pronounced; the electron beams become very strong at certain critical potentials and are indistinguishably weak at intermediate potentials. The first intensity maximum in the *A*-azimuth occurs at 54 volts. The central curve in Figure 7 shows the electron beam at this maximum. This beam occurs at a co-latitude angle of 50°. From this angle of 50° and the value of the grating constant for the *A*-azimuth, 2.15 A., we can make use of the plane grating formula $\lambda = D \sin \Theta$ to calculate wave-length. We obtain 1.65 A. and conclude that the wave-length of a 54-volt electron is 1.65 A. The curves at either side of the central curve in Figure 7 give an idea of just how selective is the occurrence of this beam.

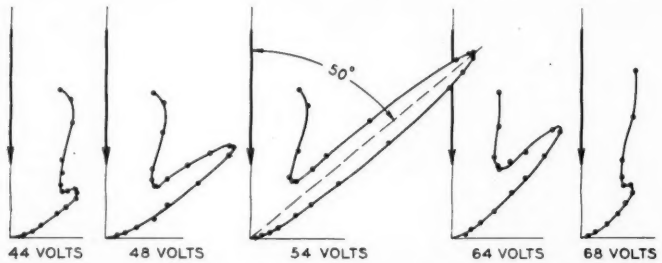


FIGURE 7.—The growth and decay of the 54-volt electron diffraction beam occurring in the *A*-azimuth of the crystal.

The first selective maximum in the *B*-azimuth occurs at 44° when the bombarding potential is 65 volts. The appearance of this beam is shown in Figure 8. Using the angle of 44° in the plane grating formula we obtain

for the wave-length of this beam 1.50 A. A 65-volt electron is thus to be thought of as having a wave-length of 1.50 A.[2]

As bombarding potential is increased, beams similar to these two occur one after another in the different azimuths. In all, 22 such beams have been discovered in the three principal azimuths of the crystal. For each of these we calculate a wave-length in a perfectly simple manner—from the observed angle of the beam and a knowledge of the grating constant, 2.15 A. or 1.24 A., whichever the case may be.

The assemblage of all these beams is strikingly similar to the assemblage of the first 22 x-ray diffraction beams which would emerge from this crystal if the primary electron beam were replaced by a beam of x-rays of adjustable wave-length. In fact there is an almost perfect one-to-one correspondence between the assemblage of electron beams and the assemblage of x-ray beams. *The electron beams are all displayed from the corresponding x-ray beams.* After all, we might expect that this would be the case from the result of the reflection experiment which showed that the electron reflection maxima occurred almost at equally spaced intervals when plotted against the square root of the voltage—but *not quite* at equal intervals. Here again we have evidence that some important factor has not yet been taken into account.

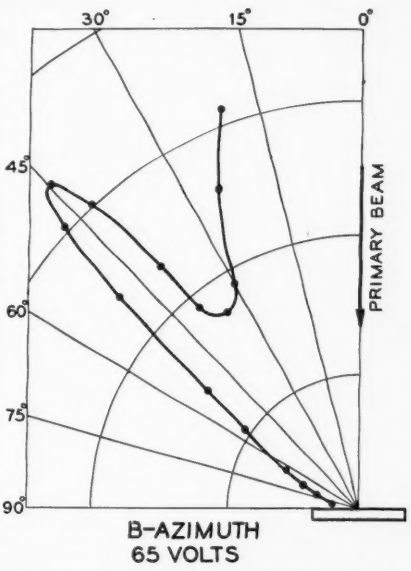


FIGURE 8.—The 65-volt diffraction beam in the *B*-azimuth.

Leaving the differences between x-ray diffraction beams and electron diffraction beams for the present, I have pointed out that a wave-length is simply calculated for each electron beam. It develops that all of the wave-lengths calculated in this manner are related in a simple way to the voltages of the electrons. These wave-lengths are all inversely proportional to the square roots of the voltages. All of the different determinations of wave-length are plotted against the reciprocal of the square root

[2] Perhaps it should be pointed out that up to this stage the calculation of wave-length is purely tentative. The proof that we are actually dealing with a diffraction phenomenon will develop gradually.

of the voltage in Figure 9. The proportionality factor in this figure is about 12. That is: $\lambda = \frac{12}{V^{1/2}}$ where V is in volts.

The fact that one can assign a wave-length to a stream of electrons is less surprising today than it would have been a few years ago. Within the last few years there have been various attempts to produce a new theory of mechanics which should be applicable to atomic systems and avoid the artificialities of the Bohr atom model. The most fruitful of these attempts was put forward by L. de Broglie nearly four years ago and has since been extensively developed by many theoretical physicists. According to this theory every problem in mechanics is really a problem in optics, and every

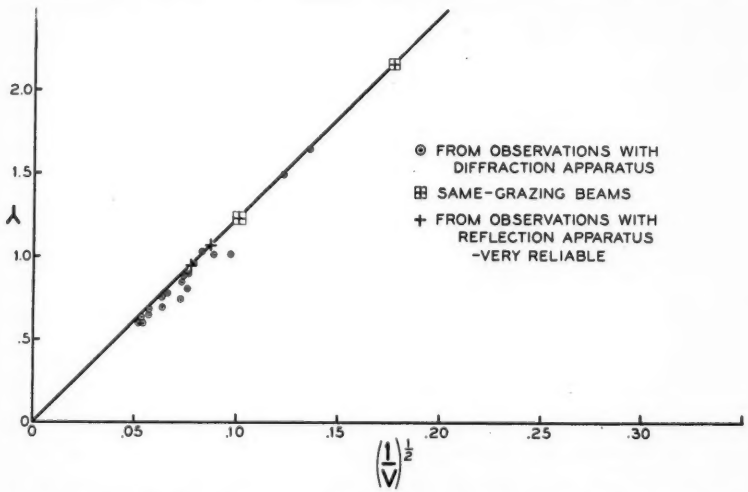


FIGURE 9.—Graphical comparison of all experimentally determined values of electron wave-lengths with the "wave-mechanics" relation $\lambda = h/mv$.

freely moving particle of mass m and velocity v is either equivalent to or has associated with it a train of waves of wave-length equal to h/mv, where h is a universal constant known as Planck's constant of action.

In carrying out the experiments which are being described in this paper, after the appearance of the first evidence that we were dealing with a diffraction phenomena, this new theory of wave mechanics has served us as a guiding principle. Actually all of the values of electron wave-lengths which we have determined are in good agreement with the wave-length assigned to a freely moving particle by this theory. Each of our values of wave-length is accurately given by the quotient of Planck's constant and the momentum of the electron. The straight line drawn on Figure 9 is

not an arbitrary line drawn to fit the observed points. It represents the theoretical relation connecting wave-length and voltage given by $\lambda = h/mv$. This relation is $\lambda = 12.2/V^{1/2}$ when λ is expressed in Angstrom units and V is in volts.

For example, this theoretical relation assigns to electrons of a speed corresponding to 32.5 volts a wave-length of 2.14 A. From the grating space of the nickel lattice we were able to determine that the wave-length of 32.5-volt electrons is 2.15 A. Similarly the grating space in the *C*-azimuth of our crystal, 1.24 A. was found to correspond to 97.5-volt electrons. The value of h/mv for 97.5 volts comes out to be exactly 1.24 A.

If all the experimentally determined wave-lengths agreed exactly with the values of h/mv, all of the points in Figure 9 would fall accurately on the line. The departures are none of them greater than can be reasonably accounted for by the uncertainty of the measurements. *It is quite certain that electrons are diffracted by a nickel crystal as if they were waves having a wave-length given by the quotient of Planck's constant and the electron momentum, mv.* This is, of course, the chief result of our work.

Rolled Oats Responsible for Furfural Discovery. Furfural may well become the chemical word familiar to every household of the coming generation, as coal-tar is to those of the present. This was the prophecy ventured by C. S. Miner of Chicago, before the Institute of Chemistry of the American Chemical Society. And the discovery that this hitherto rare chemical can be made cheaply in commercial quantities is almost an accident, the result of experiments aimed at an entirely different objective, he said.

In the preparation of rolled oats, hundreds of tons of oat hulls are left as a by-product at the end of the milling. Little use could be found for them, and they accumulated around the mills in vast quantities. In an endeavor to render them edible, at least for cattle, they were subjected to various chemical treatments, and one of these experiments resulted in the production of furfural in appreciable amounts. Since then research has followed two lines: to produce it as economically as possible, and to find new uses for it.

Furfural is very active chemically, is a solvent of wide application, and possesses many properties tending to give it commercial value. It is at present being used very extensively in the manufacture of synthetic resins and moulding compounds. Recently a light-sensitive furfural resin has been produced which is used in the preparation of printing plates. Because of its germicidal properties and also its fungicidal properties, furfural is finding application in the preventing of fermentation in glues and dextrin pastes, as well as in the preparation of disinfectants and deodorizers. Some derivatives of furfural are being used as seed disinfectants and furfural itself is used in the preparation of tree wound dressings.

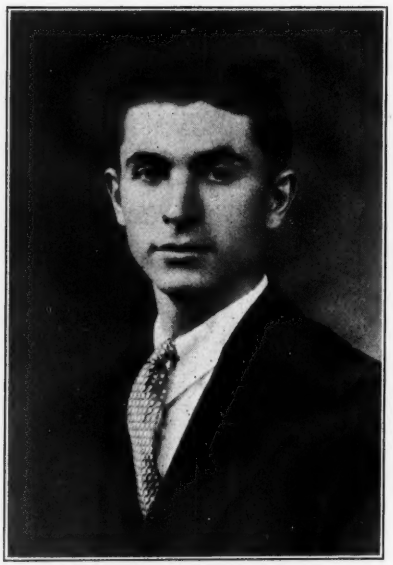
"Research men are constantly working with furfural and its derivatives and undreamed of uses for them are found every day," Mr. Miner said. "The annual crops furnish an almost inexhaustible, relatively cheap supply of raw material for the production of furfural, and as it is a highly reactive compound capable of functioning as the raw material for a wide range of chemical manufacturing processes, it may well form the basis of a branch of American chemical industry comparable in importance to the coal-tar industry in Germany."—*Science Service*

THE RELATION OF CHEMISTRY TO HEALTH AND DISEASE*

PAUL MICELI, CHAPMAN TECHNICAL HIGH SCHOOL, NEW LONDON, CONN.

A great philosopher once remarked, "To pity distress is but human, to relieve it is Godlike." If these words are true, the chemist and physician are the most divine among men, for they are ever coöperating in an effort to relieve human suffering.

From the earliest times, these two human benefactors united their arts and efforts to destroy the enemies of our health. That their coöperation is essential in combating disease is shown by their work. The chemist investigates the causes of disease, and prepares remedies for them. He then hands over the results of his investigations to the physician who administers them to humanity. Such is the method by which the world is made a better place in which to live. Most of the discoveries which have done so much to advance the medical science are products of the chemical laboratory. These discoveries are not confined to any one particular branch of medicine, for the chemist does not confine his work. He lends his helping hand to the one which is in most need of his services.



PAUL MICELI

The fields in which he has been most successful are: (1) in preventing disease, (2) in preparing antitoxins, (3) in preparing anesthetics, (4) in preparing specific drugs for specific diseases, (5) in the study of the organs of secretion, and (6) in the study of the constituents and needs of our body.

Preventing Disease

The prevention of disease is the keynote of modern medical practice. Pasteur's discovery, that diseases are caused by germs which enter the blood and multiply on an enormous scale, served as a starting point on which chemists based their work. It was found that infectious germs were carried about from place to place by such low forms of life as rats, flies, and mos-

* Prize-winning high-school essay, 1927–28.

quitoes; and that they were most numerous in unsanitary places. A movement was immediately directed toward the extermination of these insects, and the improvement of the sanitary conditions. Breeding places of flies and mosquitoes were destroyed, and in many cases where this was impossible, chemicals were prepared to kill the eggs. Cities established chemical methods of purifying the water supply, and suitable places for the disposal of the waste. Sanitary laws were put into force, and the public was instructed to observe them for its own welfare. The result of this movement was an immediate drop in the number of sick persons. The improvement of the sanitary conditions alone has done more to prevent disease than all the medicines to cure them.

The man to whom we are greatly indebted for the prevention of many diseases in surgery is Lord Lister. Lister discovered that the fevers and deaths which usually followed surgical operations were due to bacteria which gained access to the tissues of a wound. To prevent this, he developed a careful system of disinfecting everything which came in direct contact with the cells of the body. He invented antiseptic dressings which excluded bacteria, and assisted the tissues to heal themselves. The adoption of Lister's antiseptic system in surgery has done away with a great deal of unnecessary suffering, and has made possible difficult operations.

Preparation of Antitoxins

The preparation of antitoxins was first started by Louis Pasteur, a great chemist and human benefactor. And it may be truly said that Pasteur did for medicine what Lister did for surgery. Pasteur discovered that diseases are caused by germs which enter the blood, and multiply on an enormous scale. To prevent their development, he prepared antitoxins. In so doing, he founded a new branch of medicine known as serum therapy by which antitoxins are developed in the blood of animals for inoculation against disease. Today this science forms one of man's most useful weapons in combating disease. With the aid of the chemist in isolating pure principles of antitoxins from the fluids which are now injected in our blood, diseases will be more quickly and thoroughly destroyed.

Anesthetics Revolutionize Surgery

Ancient surgery was extremely barbarous. The flow of blood was stopped by applying a red hot iron to the wound. Operations were usually performed without anesthetics, and they were not only difficult to perform, but caused great suffering. For these reasons, operations were avoided as much as possible. But the discovery and use of anesthetics immediately revolutionized surgery. For operations could now be performed under the most favorable conditions without suffering to the patient.

For this great blessing mankind is chiefly indebted to Horace Wells who used nitrous oxide, W. T. C. Morton who used ether, and Sir James Simpson who used chloroform. The first of these two men employed anesthetics in dentistry, while Simpson employed ether and chloroform in obstetrics. The success of these three men immediately brought into prominence the value of anesthetics, and their use has been steadily increasing until today they are used almost universally in all forms of surgical operations. It will be noticed that these compounds are products of the chemical laboratory. The formulas for nitrous oxide, ether, and chloroform are N_2O, $(C_2H_5)_2O$, and $CHCl_3$, respectively.

Anesthetics are invaluable in surgery. By their use surgeons can perform difficult operations without pain to the patient. This accounts for the large number of operations which are being performed today; thus restoring life and health where we cannot look for help from medicines. Hayes and Moon in their book "Modern History" say: "These three men did more to relieve human suffering than Alexander, Caesar, and Napoleon did to cause it."

Specific Drugs

In an attempt to relieve human suffering as soon as possible, and to destroy disease with the same certainty that two and two make four, the chemist tries to prepare specific drugs for specific diseases. This task is entirely an affair of the chemical laboratory. The plan of action is two-fold: (1) to improve natural remedies, and (2) to prepare specific medicaments from some promising compound.

In the first case, the chemist starts out with a known natural remedy; makes an exhaustive study of it, and with the information thus derived, improves the natural product. An instance of the success of the chemist with this method was the improvement of the remedy for leprosy by preparing pure acids from the disagreeable chaulmoogra oil. By combining these acids with ethyl alcohol, an agreeable drug has been prepared which can be used hypodermically with great success against leprosy.

The second method of attack is to start with some promising compound and alter the formation of the molecule until the desired compound is obtained. This method is the more difficult of the two, since success depends upon the compound chosen and the perseverance of the experimenter. The first man to succeed by this method was Paul Ehrlich, a German chemist and physician. He started out to find a specific for that loathsome and widespread disease, syphilis; and he chose for his compound a dye. For two years he labored together with a host of assistant chemists. 605 compounds were prepared, and each one of these was a failure. One would think that he would have abandoned the project long before. But it seems to be a characteristic of the chemist never to give up. Ehrlich

was justly rewarded for his perseverance for his "606" compound, better known as salvarsan, proved to be the object of his search. This discovery was one of the outstanding achievements of the nineteenth century in medicine. It was a great achievement for Ehrlich, but it was a greater one for chemistry because it demonstrated the chemist's power of transforming one form of matter into another form more serviceable to man.

The work of Paul Ehrlich with dyes led to the discovery of many powerful antiseptics and selective poisons for infectious microbes, and it opened the road to an entirely new way of combating disease. The success of the chemist in this field has been great. Many more useful medicines have been prepared from the black and foul-smelling coal tar. Notable among these are mercurochrome and gentian violet for blood poisoning, acriflavine for gonorrhea, and rivanol as an antiseptic for internal use.

In the whole history of medicine only two absolute specifics have been found. They are quinine for malaria and the famous compound, salvarsan, for African sleeping sickness and syphilis. Chemists are spending a great deal of time in this field, and as a result of their efforts many near specifics have been prepared. The value of specifics is great, and one of the chief aims of the chemist is to discover specifics for each disease. The only way that we can help him accomplish this task is by giving him our hearty support.

The Organs of Secretion

Within recent years chemists have devoted considerable time to the study of the organs of secretion. These organs were not known a century ago, nor was their existence suspected by physicians. The secretions of these glands are of vital importance to life and health since they control the growth, the digestion of food, the actions of various parts of the body, and produce powerful drugs which combat disease.

The glands of the body are divided into two groups: (1) glands with ducts, such as the salivary glands and the pancreas; and (2) ductless glands, the most important of which are the thyroid, parathyroid, thymus, gonads, pineal, pituitary, adrenals, and ductless pancreas. Glands having ducts pour their secretion into the stomach and intestines for digestive purposes, while the ductless glands pour theirs directly into the blood stream.

The secretions of these glands are known as hormones; they are chemical in nature, but extremely poisonous. Chemists have determined the chemical composition of some of these drugs, and now they are prepared artificially. Adrenalin, the active principle of the adrenals, which are located just above the kidneys, was isolated by John Abel, of The Johns Hopkins University, and later a Japanese chemist, J. Takamine, obtained the principle in pure crystal form. Its composition was finally determined, and it is now prepared artificially.

Adrenalin is a very important drug. When injected hypodermically, it allays very quickly the spasms of acute bronchial asthma. When applied externally to a bleeding wound, it stops hemorrhage instantly, thus enabling the surgeon to perform bloodless operations. Adrenalin strengthens and stimulates the action of the heart which makes it invaluable in the treatment of pneumonia. This drug is also used extensively in preparing greatly weakened or aged persons to withstand the shock of an operation.

Dr. E. C. Kendall of the Mayo Foundation isolated thyroxin, the active principle of the thyroid glands, which regulates the combustion of our food. This principle is so very active that an occasional dose of a minute fraction of a gram is sufficient to cure cases of cretinism and myxedema. For many years this drug was very expensive, due to its scarcity, and its artificial preparation had been looked upon by many physicians. Finally, Dr. C. R. Harrington and Professor George Barger prepared a drug from iodine and a coal-tar product, said to be fully as effective upon human beings as the thyroxin obtained from the gland. The discovery of this drug was another achievement of the chemist, and the reward of ten years of research by organic chemists throughout the world.

Another great triumph of the chemist in relieving human suffering was brought about by the discovery of insulin, the active principle of the ductless pancreas. Thousands of diabetic sufferers are now finding relief by its use.

Chemists are making a thorough study of the other organs of secretion, especially the pituitary glands which control the growth. The isolation and artificial preparation of the active principles of these glands will be another great stride toward the permanent establishment of health, and the abolition of defective and ill-formed beings.

The Constituents and Needs of Our Body

We have already seen that the normal functioning of the organs of secretion is essential to good health. There is still another condition upon which good health depends and that is a proper adjustment of the components of our blood. The importance of a knowledge of the composition of the blood under normal conditions is obvious. Once determined, the missing elements and compounds of the blood when it is abnormal can be supplied, and good health would naturally follow. The chemist has already made some progress in determining some of its compounds, and we may expect the solution of this problem in the course of time.

The material needed by the blood to meet the needs in the body is supplied by our food. Hence, those foods should be eaten which will give the required substances. These substances are termed vitamins, and traces of their presence is found in nearly all fresh foods. From a lack of vitamins

growth may cease and various diseases result. Dr. E. V. McCollum has designated these substances by the letters of the alphabet in the order in which they have been discovered. They may be described in the following manner: *Vitamin A*—promotes growth and prevents blindness, *Vitamin B*—prevents beri beri and whets the appetite, *Vitamin C*—prevents scurvy, *Vitamin D*—prevents rickets, *Vitamin E*—promotes fertility. Chemists have made some progress in finding the substances which furnish these vitamins, but very little is known about them. To discover their character and composition is now one of the objects of the chemist. The solution of this problem is awaited by mankind, and again we must look in the direction of the chemist.

Conclusion

Thus, in six realms, we have seen the work and achievements of the chemist. But the chemist has only begun his work, and chemico-medical research is really in its infancy. Through the coöperation of the chemist and physician, the medical science has advanced by leaps and bounds. All this goes to prove conclusively the vast importance of chemistry and the prophetic words of Louis Pasteur when he said: "Science is the soul and prosperity of nations, and the living source of all progress."

Bibliography

"Research in Medical Practice," *Science*, **66,** 260 (Sept. 16, 1927).

"Interdependence of Science and Medicine," Lord Lister, *Sci. Mo.*, **25,** 193–212 (1927).

"Century of Medical Progress," H. Rolleston, *Quar.*, **245,** 170–89 (July, 1925).

"Life of Pasteur," R. Vallery-Radot, Doubleday, Doran & Co., Inc.

"Discovery of the Spirit and Service of Science," Sir Richard Gregory, Chemical Foundation, Inc.

"The Future Independence and Progress of American Medicine in the Age of Chemistry," by a Committee of American Scientists, Chemical Foundation, Inc.

"Modern History," by Hayes and Moon.

"The Romance of Chemistry," by William Foster, The Century Co.

"The Story of Chemistry," by Floyd L. Darrow, The Bobbs Merrill Co.

Finds Color Test for Vitamin A Reliable. The color test for vitamin A in cod-liver oil has now been proved thoroughly reliable when compared with the old, biological method of testing for the presence of this vitamin, according to experiments carried on at laboratories in the University of Sheffield; University College, London; King's College for Women, London; The Lister Institute; and the University of Oslo.

At these laboratories several different samples of the oil were tested by the biological method, which is a feeding method carried out on experimental animals, and the same oils were tested by the color test by Dr. Otto Rosenheim, of the National Institute for Medical Research, who originally devised the color test. The results were so similar that the reliability of the color test was proved without any doubt.

However, the two methods are now to be compared for other substances such as butter containing vitamin A.—*Science Service*

THE RELATION OF CHEMISTRY TO THE ENRICHMENT OF LIFE*

RUTH LESLIE, BONHAM HIGH SCHOOL, BONHAM, TEXAS

Through a short six months' study of Chemistry, I feel that I have gained only a slight acquaintance with this great science, but through the writings of many chemists, I am enabled to see how great a friend Chemistry is to man—how greatly it enriches his life. As I study the marvelous things that these devoted disciples of Chemistry have learned, I can see Chemistry in one great rôle—the Liberator of Mankind. At times Chemistry assumes the toil-worn, earnest visage of Discoverer; again its guise is that of Creator. But always Chemistry is the Liberator. No phase of modern life remains wholly unaffected by its freeing touch. Any division of Chemistry's great work would necessarily involve an overlapping, but to me, its influence as Liberator is embraced in this classification: first, the liberation of mankind from nature; second, the liberation of living creatures from disease and pain; third, the liberation of humanity from tyranny.

RUTH LESLIE

No matter which way we may turn, we see how Chemistry has released and is releasing man from the limitations of nature. But yesterday there was a mountain yonder—a rugged, unyielding mountain that stood in the way of one of man's great highway projects. Now it lies in scattered fragments; but did man attack it with pick and shovel? Perhaps that is what he would have been forced to do if Chemistry, the Liberator, had not come to his aid with some apparently harmless black sticks, which when properly placed and ignited at the right moment bring even a mountain to ruin.

Here we see a barren little farm. Must its owner be content to take only its poor yield as his reward for hard labor? It seems that he must. But look! His neighbor's farm is fertile and rich. Wherein does the difference

* Prize-winning high-school essay, 1927–28.

lie? Ah, you have guessed, the neighbor feeds his soil. He realizes that it must have a balanced ration if it is to produce properly. So he feeds it nitrates to supply the nitrogen that it needs for weediness; the potassium salts that it requires for rigidity and strength; and phosphates to make it bear fruit abundantly. Nature, by leaving both farms originally poor, had succeeded in making life hard for those who lived there, until one man accepted the aid that Chemistry offered, and freed himself.

Many are the people who have suffered from the ravages of insects which destroy their crops. Helpless were they until Chemistry stepped in and found a remedy. Insects which destroy fruit trees have been driven effectively away by the use of sprays, and even those scourges of the cotton-growing South—the boll weevil and the boll worm—are being brought under control. Last year, my father had the only successful cotton crop in this immediate locality because he prevented the destruction of his plants by dusting them with calcium arsenate. Yet how much more can Chemistry help the cotton farmer by preparing cheaper, surer remedies against these destroyers.

Not only in agriculture is Chemistry freeing man from nature but in manufacturing as well. Man no longer has to depend upon nature for materials for special uses. Quite often nature does not have the thing that fits his need. Chemistry has taught man to make steel for various implements, varying its properties to exactly fit the need. From the fuel which nature supplies, man has learned through Chemistry's aid to extract or manufacture materials which are better heat-producers than the natural products. Coke and gasoline are much more valuable to him as fuel than bituminous coal and crude petroleum; and, besides that, Chemistry has made the by-products of these great fuels into more useful substances than the originals. Nature's dyes are often scarce and hard to get; but Chemistry has made even more beautiful and durable colors, to dye the fibers gained from nature or manufactured by man by chemical processes.

Nature's building stone is quite often inaccessible and at best difficult to obtain; so Chemistry has taught man the use of concrete which he himself can make, and, what is more, from which he can fashion a structure which is all in one piece. Even if man does not build his house from stone or concrete he can make the wood from which he constructs it almost as durable by the use of paint, that marvelous mixture which protects the wood from the damages of wind, sun, and rain.

From the discomforts which Nature imposes upon humanity, Chemistry is the great Liberator. How many a poor housewife—especially in the country—has toiled almost in vain over her laundry because the water was hard! How many bars of soap has she used with no effect! Temporarily hard water she learned to soften by boiling; but that which seemed permanently hard could be softened only by a chemical process—the

addition of washing soda—sodium carbonate. "There's no comfort on earth like ice in hot weather" is the slogan of many an ice company; but here in Texas we would not have that comfort if Chemistry had not helped. Though it gets terribly cold at times during the winter, storing away the ice that is formed would be an utter impossibility because there is not enough of it. But how we would suffer if we did not have ice in the summer time! No ice cream, no ice water, no fresh cold fruits, vegetables, eggs, or milk—we could not comfortably exist. Chemistry indeed has saved us from discomfort.

Perhaps best of all, Chemistry is freeing man from the natural limitations of time and space. The great means in this liberation has been gasoline. In the first place, gasoline is the perfect motor fuel. It is composed simply of hydrogen and carbon. It gives on complete combustion only water and carbon dioxide gas. It contains no ash; it is a liquid at ordinary temperatures, but can easily be converted into a gas for combustion. It does not freeze in cold weather, or rot. It does not stain things and is not unpleasant to sight or smell. The very perfection of the fuel is making possible the marvelous development of automobile and airplane, the greatest conquerors of time and space. The automobile reaches places to which the steam engine cannot penetrate. The airplane gives man wings. With these two he can speed at will across continent or ocean. But now we are told that the oil which supplies our gasoline is rapidly giving out; so the world puts its trust in Chemistry to solve the problem which is so far-reaching in its interest—the making of a fuel to take satisfactorily the place of gasoline.

I had scarcely thought of the relation of Chemistry to the preservation of health and the liberation from disease until I read the life of Pasteur. My idea had always been that medicine alone was responsible for the health of the world; but from that book I learned that not until medicine joined hands with Chemistry did it make progress in the liberation of living creatures from disease.

In the first place, it was a chemist who proved the germ theory and exploded the theory of spontaneous generation. When Pasteur began his work, the bacterial origin of diseases was merely suspected, and the idea ridiculed. As a result of Pasteur's work, it is now generally known that most, if not all, common diseases are caused by living microscopic organisms, either bacteria or small animal parasites. And when the bacteria are discovered, means of preventing their taking hold upon the body may be prepared in the form of vaccines and antitoxins. Here again, we find Pasteur, the chemist, the great leader in careful research and final success. Pasteur saved many animals from suffering and many owners from loss by his isolation of anthrax bacteria and his discovery of an effective vaccine. But his great work in the service of mankind is his victory over hydrophobia.

The energy and patience he expended can never be measured; but on the other hand neither can the greatness of his achievement nor the inspiration he gave by it be measured except as we observe their liberating effect upon man. Pasteur's disciple and co-worker, Dr. Roux, lifted a shadow of dread and despair from every mother's heart when he found a cure for diphtheria in the form of an antitoxin. Both were chemists, and through them Chemistry loosed the chains of two horrible "incurable" diseases—chains which had held man helpless and suffering throughout the ages.

But these are not all. Chemistry has freed man from another curse, leprosy, by the isolation of clean pure acids from the natural remedy, chaulmoogra oil. These acids when mixed with ethyl alcohol can be used hypodermically, and seventy-eight cases have been reported cured by the use of this new drug. Hookworm and epilepsy have also been conquered recently. The cures for all these apparently hopeless diseases have been accomplished by the active coöperation of Chemistry and medicine.

With the discovery of microbes, we find another great development in the liberation from disease, advances in antisepsis. Before the establishment of the germ theory, surgeons could not see how their instruments carried infection from one patient to another. Pasteur tried to show them the necessity of putting "through a flame" all their instruments and dressings, even their hands. From his efforts has grown that science of disease prevention, to which the chemist contributes antiseptics which kill germs but do not harm tissue. By this use of antiseptics, with the aid of anesthesia, the surgeon can enter practically all parts of the body without fear of leaving behind those germs which will grow and ruin his work.

The liberation from pain and the liberation from disease are in a sense synonymous, but the liberation from pain has a wider field of application. Without anesthetics, general and local, surgery and dentistry could never have reached their present degree of perfection; and it is the chemist who has discovered and prepared these anesthetics. We are all more or less familiar with ether, chloroform, and laughing gas; and if we have often visited a dentist's office we are familiar with cocaine. Cocaine is a natural remedy; but it would never have reached its great usefulness in the liberation from pain if the chemist had not taken a hand. The solution of this white, crystalline substance was used as a local anesthetic from the time of the discovery of its property of suppressing pain. But the grave defects of its difficulty to be sterilized and its poisonous effect brought it under great distrust. Cocaine was then placed under the diligent scrutiny of chemists who found that only one part of the molecule has anesthetic effects, that another part is related to the deadly principle of hemlocks, conine, and that another part is related to nicotine. Then the chemist was in a position to improve upon nature, and today we have artificial local anesthetics which possess the virtues of cocaine but do not have its ex-

cessive toxicity. These products—procaine or novocaine, beta-eucaine, etc.—have proved so valuable to surgery that they are now being used even in major operations.

One usually thinks of liberation from tyranny as involving the overthrow of a despot, or a group of despotic aristocrats, by means of bloodshed. Chemistry, however, more efficiently than a revolution, accomplishes the same overthrow of an aristocracy. An aristocracy, it is said, cannot exist without differences in dress; Chemistry is now abolishing those differences.

In the first place, Chemistry has robbed royalty of its most distinctive insignia, Tyrian purple. In ancient times few were "porphyrogene," that is, "born to the purple," for only princes or their wealthy rivals could afford to pay six hundred dollars a pound for crimsoned linen. Phoenician merchants made fortunes in the trade of this precious dye, for the snail-like shellfish which secreted it thrived on their coast. With the fall of Tyre its use became one of the "lost arts." In 1909, however, Friedlander put an end to this idea by analyzing Tyrian purple and finding it to be already known to chemists. It had required 12,000 mollusks to supply the little materials needed for the analysis, but once having identified it, the chemist could make it by the ton. So, to be born to the purple is no longer a distinction. It is the heritage of every child.

But not only has Tyrian purple been given to the multitudes. Shades and hues more gorgeous, much more beautiful and becoming, have been prepared from that former waste product—coal tar. Then, too, the fine silks which were so long in the hands of the rich alone have found a substitute in a product made by a chemical process from cellulose. The perfumes which in ancient times were treasures of kings are now made from coal tar, and given to shop girl and princess alike.

It is the chemist who has discovered and perfected these processes by which luxuries are made luxuries no longer, but are put in the hands of everyone. Applied Chemistry is helping to establish real democracy such as legislation has ever failed to establish.

Chemistry is the Liberator of man not only from the tyranny of man, but from the harsher tyranny of ignorance. The art of printing is rightly considered the greatest of forces in the liberation of mankind from ignorance, but, to me, printing is more of a chemical process than it appears on the surface. To begin with, what would be the value of printing without paper? The Romans made use of type in stamping their coins; but did the mere use of type advance them intellectually? No, it is paper that has made printing so great a force in freeing man from ignorance. And paper is the result of a chemical process, by which the cellulose of a tree is changed to a clear, thin, smooth sheet. Then, again, what could the type and paper do without the ink? The symbols and pictures on the page make the process a factor in the enlightenment of the world. And the type itself?

It too has felt the hand of the chemist, for the metal from which it is made has been subjected to suitable chemical processes.

The service of Chemistry, the Liberator, is making man's life immeasurably richer and fuller year by year. From his weak shoulders it is lifting a load of poverty and dependence upon the earth. It is making him free, the master of nature. Chemistry is dispelling disease and pain and leaving man whole and strong and happy. Its power is gradually lifting him from the oppression of his fellows and the darker oppression of ignorance. And the glory of Chemistry's work is that it never ceases, but with every month, every year adds some new factor to the uplifting and enriching of the life of humanity.

Bibliography

"Creative Chemistry," by Edwin E. Slosson.

"The Life of Pasteur," by R. Vallery-Radot.

"Science Remaking the World," by Otis W. Caldwell and Edwin E. Slosson.

"The Future Independence and Progress of American Medicine in the Age of Chemistry."

Using Science to Brown Cookies. Just how brown is the "golden brown" cookie of the recipe books and how does it get that way? Three scientists, Prof. C. H. Bailey, Eva L. Stephens, and Alice M. Child, of the Minnesota Experiment Station, have found a way to tell and have reported it to the American Association of Cereal Chemists.

An instrument called a spectrophotometer is used to measure the color quantitatively. The reflection of light from the cookies is compared with that from a standard of a certain degree of brownness, and the color of the cookies is determined by mathematics. The color of the cookies depends somewhat on the color of the molasses, as every cook knows. Also, increasing the amount of the baking soda makes the cookies darker as does increased temperature of baking. By the use of this instrument it is possible to determine the difference in color of baked products which results from changing the recipe or the time or temperature of baking.—*Science Service*

Borax Discovered to Be Deadly to Mosquito Larvae. Borax has had another use added to the long list of things it is good for, by Prof. Robert Matheson and E. H. Hinman of Cornell University. They have discovered that a concentration of one and one-half parts in a thousand of water is very quickly fatal to the larvae, or "wigglers," of mosquitoes that breed in rainwater barrels, cisterns, and other exposed reservoirs. The borax seems to hold its larvae-killing properties for a long time; one experiment ran from July 25th to September 7th of last year without any sign of weakening at the end.

The two entomologists add however that borax should be used only where its possible effects on other animals and on plant life will be of no consequence. They are of the opinion that a cheap form of the chemical can be successfully marketed for mosquito-fighting purposes.

In the course of their experiments they raised large numbers of mosquito larvae, which had to be fed artificially. They state that they found common compressed yeast, such as goes into the collegiate "double malted," very good wiggler food.—*Science Service*

THE RELATION OF CHEMISTRY TO AGRICULTURE*

JOHN B. RAE, CLASSICAL HIGH SCHOOL, PROVIDENCE, R. I.

The legislator was visiting an old friend whom he had not seen for years. They had grown up together; they had gone through high school together; they had entered college together. There they had separated: one to study law; the other, chemistry. He was a successful lawyer and a power in politics; his friend was an authority upon agricultural chemistry. It was because of this fact that he had come to his friend, seeking from him advice in regard to the demands of his farming constituents for government relief—demands that became more insistent every day.

JOHN B. RAE

"Personally," said the lawyer, "I believe that, while the government ought to promote industry by helpful legislation, actual interference should be reduced to the minimum. Accordingly I am opposed to price-fixing by Congress. It is my opinion that farming should be on an up-to-date, scientific basis, like every other great industry in the country. I advocate coöperative marketing, wider use of farm machinery, and more extensive application of the results of chemical research. Since I have only a vague idea of what agricultural chemistry actually is, I have come to ask you to give me a clearer understanding of the subject."

"I believe that I can be of some assistance to you," replied the chemist. "My studies have brought me into contact with the farm problem. It seems to me that the root of the trouble is that the farmer is not receiving an adequate return for his labor. Farm machinery helps him to harvest his crop; coöperative marketing helps him to sell it; but first of all the soil must be made to yield a crop sufficient to make his labor worthwhile. After the soil has been cultivated for several years the need of fertilization becomes an acute problem.

"Since man first began to till the soil, great minds have been turned to this

* Prize-winning high-school essay, 1927–28.

problem. The Mosaic laws enjoined the Israelites to let their fields rest every seventh year. Hesiod of primitive Hellas, and Virgil of imperial Rome, alike wrote voluminous directions to the farmer for improving his soil. By observation and experience the ancients gained a surprising amount of knowledge about agriculture. Nevertheless, they knew only effects; it was left to the chemist to study causes.

"The first aim of the chemist was to find out how plants grow. We have learned that they are built from chemicals in the soil and in the air by a process so delicate that man's chemistry is crude by comparison. Some chemicals are more essential than others for plant nutrition. The supply of these is rapidly depleted in cultivated soils. Our work is to restore these chemicals in sufficient quantities to maintain fertility."

"If you don't mind, I should like you to tell me the details of this matter," interrupted the lawyer. "The farmers in my State suffer because of poor soil, so that anything concerning fertilization interests them."

"Very well," said his friend, "The problem of replenishing the soil centers mainly around three chemicals: nitrogen, phosphorous, and potash. They are absorbed by crops in such quantities that it is necessary for man to aid nature in restoring them.

"It used to seem strange that soils should lack nitrogen, as most of the atmosphere about us consists of this chemical. We have since discovered that plants cannot use atmospheric nitrogen. It must be converted into nitrates. This fixation is the work of certain microörganisms in the soil. Leguminous plants, especially clover, seem to stimulate these bacteria. That is why clover is such a fine rotational crop. This natural supply is very great, but not great enough for our needs. We must supply what is lacking. Animal manures, which are rich in nitrogen, have been used as fertilizers since man first began to cultivate the soil. The nitrate fields of Chile ship great quantities of excellent fertilizer to all parts of the world. Unfortunately, the supply is not inexhaustible. Therefore, we are driven to seek some way of "fixing" atmospheric nitrogen. Already we have discovered several processes. The electric arc method is useful where plenty of cheap power is available. The cyanide method requires less power, but its product is not so efficient as a fertilizer. The Muscle Shoals question arose in Congress because it was thought that nitrogen could be manufactured there. A chemical process was used in Germany during the war to provide a supply of this chemical for military purposes. Eventually, we shall develop an air-nitrogen industry that will furnish the needs of agriculture.

"As for phosphorus, we have found that bones contain a large amount of it. We have also discovered means of producing it from certain minerals.

"In salt mines some salts that were formerly useless are obtained. Chemistry found that these waste minerals are rich in potash. Thus a worthless product has been turned into a valuable fertilizer.

"Chemical analysis can tell the farmer what are the particular needs of his soil. Commercial fertilizers are manufactured containing proportionate amounts of the essential chemicals. Chemistry can also prevent the farmer from being defrauded by unscrupulous manufacturers.

"Protection of crops is another important part of the chemists' work. Insect pests are sometimes transported from one region to another. There, freed from their natural enemies, they attain heights of destructiveness. The best way to combat them is to find these natural enemies and introduce them to the infested locality. This research takes time, and in the meanwhile chemical warfare must be resorted to in order to save the crops. Arsenic has been found to be a good insecticide, but much study was required to find some form of it that would not harm the crops. Lead arsenate was the solution. Pyrethrum, which is made from the powdered head of certain plants of the Chrysanthemum species, was discovered by chemists. Petroleum products have been of good service in this field, but here again it was necessary to produce a mixture that would not harm the foliage.

"Fungi are destroyed by using chemical compounds which contain copper as a basic constituent.

"By these various methods we are fighting such pests as the cotton boll weevil, the gipsy moth, and the corn borer. It has been a long and costly struggle, but I am confident that chemistry will win out in the end."

Here the legislator again interrupted. "It is evident," he said, "that chemistry will eventually be indispensable to the farmer. Nevertheless, I do not see how it assists him to sell his crop. It will not do him much good to raise a great harvest if there is no market to dispose of it."

"That is not strictly a chemical problem," replied the chemist. "Yet I believe that in some ways we do help the farmer to settle this difficulty. In these days when food is made by machines in great factories, instead of by hand in the homes, it is the work of the chemist to see that a high standard of quality is maintained. In addition, numerous by-products are extracted from farm products by chemical means. Any new discovery in this field may open a new market for the farmer. Some of our staple goods could not be produced without the chemists. I suppose you want some specific cases?"

The legislator nodded assent. "Then," continued the chemist, "consider the great cereal food industry that exists in this country. It has grown very rapidly in the past few years. Most of this expansion is due to chemical research. In some cases parts of the grain that before had been useful only as fodder for animals were shown to be valuable foods for the human body. Think, for instance, how many people ate bran even a decade ago.

"There are many other by-products. From barley we get malt; from

corn we get hominy and various starches; it would take too long to go through the entire list. You would be surprised to learn how many things that we now consider necessities have their origin in chemical research.

"In the growing and manufacturing of sugar, chemistry is indispensable. As you probably know, sugar is obtained from two plants, the cane and the beet. No very large area in our country is adapted to the growing of sugar cane. Nevertheless, there is enough to make the subject worthy of our attention. Besides, America has extensive interests in the development of this industry in the West Indies. In the first place, sugar cane requires strict fertilization. If careless methods are used, the quality of the crop depreciates very rapidly. Then the process of refining is very largely a chemical one. Tests have to be made at each step of the proceedings to make sure that all is satisfactory.

"The sugar beet is a plant more directly affecting the American farmer. Its properties were discovered by European chemists when Napoleon's "Continental Blockade" created a shortage of that article. During the beet season the refineries are in operation day and night, Sundays, and holidays. The strictest chemical supervision is required. The slightest stoppage for any reason may mean a great financial loss, as well as a difference in the quality of the product. The sugar beet is also a valuable rotational crop, as its roots go deep into the ground and bring to the surface rich soil that other crops could not reach.

"You know, of course, that immense quantities of canned fruit and vegetables are consumed in this country today. Without chemistry this industry could not exist. The cans have to be sterilized; the contents have to be turned into a form that will encourage preservation; and the containers have to be sealed very carefully. The development of improved methods of canning enables us to grow great quantities of fruit without flooding the market, since we can preserve for future use the surplus crop, which otherwise would have to be sold very cheaply or allowed to rot away.

"From fruit, as from grain, the chemist extracts many useful by-products. Apples give us pectin which saves several hours of boiling in making jelly from fruit juices that are slow in thickening otherwise. Citrus fruits yield flavoring extracts which, used in beverages that have supplanted alcoholic drinks, are as much in demand as are the fruits themselves.

"There is another matter in regard to fruit in which the chemist plays an important part. The fruit which reaches the market first commands the highest price. In their anxiety to get ahead of their competitors some growers were even sending immature fruits to market at the beginning of the season. Of course, legislation was demanded in order to stop the practice. Then the question arose, "How can we tell whether fruit is immature or not?" The problem was turned over to the chemists. Now fruit must

come up to a certain standard based upon its chemical contents, before it can be offered to the consumer."

"Now that you have said so much," remarked the lawyer, "you might as well complete your lecture and tell me something about what you are doing for livestock."

"Very well," said his friend. "There has been much discussion recently about the relative values of animals and crops as producers of food for the human race. Whatever may be said, there is no doubt that an important part of our food supply comes from cattle, sheep, and other animals of the farm and ranch. Accordingly, we cannot neglect them in our research. One of our objects has been to find out what kind of food, and how much of it, produces the best results in the various breeds. In the production of meat, chemistry is becoming more and more important. The employment of this science is essential for the maintenance of purity. Lard, glycerine, and fertilizers may be mentioned as some of the other contributions of animals to our welfare.

"We cannot overlook milk. It is, perhaps, the most important contribution of the animal to us. The greatest thing that chemistry has done for milk was accomplished by that benefactor of mankind, Louis Pasteur. He originated a process, called pasteurization in honor of him, by which milk can be purified. There are also other important discoveries. We know of what milk is composed, and also what proportion of the various ingredients are in it. Therefore, it is not difficult to detect adulteration in milk. We can also prevent fraud in cream, butter, and cheese, which are by-products of the dairy industry. Condensed and evaporated milk are concentrated forms adapted for special uses.

"I have now told you some of the outstanding things which chemistry does for the farmer. We are not combating nature; we are merely supplementing her efforts to meet the complex demands of life. Our work is to find out why things are so and whether or not they can be improved. Chemistry may not produce an immediate remedy for the agricultural situation, but I know that a better understanding of the chemistry of plant life would eventually prove very profitable for the farmer. Perhaps increased application of this science would result in the restoration of the abandoned farms of New England and the other Eastern States.

"There can be no question of the inadvisability of restrictions upon agriculture. The population of our country is steadily growing. Europe looks to us for a great part of its food supply. Every now and again someone announces that the world will soon be over-populated. To meet the demand we must develop agricultural science until every available square foot of earth is producing a maximum yield of crops.

"We do not know what the future holds in store for us. We do know,

however, that chemistry, like every other science, is never at rest but is always moving forward.

"Perhaps some future discovery will revolutionize agriculture. Such a thing is possible; science has often caused an upheaval in the world. Think of what the discovery of gunpowder meant to history. Consider what steam and electricity have done in our own day. In my opinion the duty of the government is to encourage scientific research, not to subsidize the farmers."

So ended the chemist's discourse. Then the legislator spoke.

"I see," he said. "While Congress is battling over the farm problem, and while statisticians are alarmed by the specter of over-population, you fellows are quietly working away in your laboratories on experiments that will accomplish far more than any legislation."

Bibliography

"Chemistry in Agriculture," edited by Joseph H. Chamberlain—384 pages.

Peroxides Useful for Something Besides Blondes. Although the average citizen is familiar with only one peroxide, hydrogen peroxide, which he uses for a mouth-wash and his flapper daughter may use for a hair bleach if he doesn't watch her, peroxides of various other kinds play a more important part in his daily life than is usually realized. Some of the things for which peroxides are useful were described before the recent Institute of Chemistry of the American Chemical Society, by Dr. V. R. Kokatnur, of Arlington, N. J.

"Hydrogen peroxide can be described as being composed of two parts, *viz.*, oxide head and hydrogen trunk," said Dr. Kokatnur. "If this oxide head of hydrogen peroxide is attached to a trunk of a different genus, such as one severed from organic compounds, we get an organic peroxide.

"Nature has many such organic peroxides. When a drying oil, such as linseed oil, tung oil, or turpentine, dries in air it forms a tough film of organic peroxides and in a sense the paint and varnish industry may be said to depend on this discovery. When a beautifully colored leaf or flower fades or changes its color in the fall, it is perhaps due to a whole or part bleaching of such colors by peroxide formation.

"The oxygen of organic peroxides is of an active type and is many hundred times more powerful than oxygen of hydrogen peroxide. This property makes organic peroxides extremely useful in arts and industries. Thus nearly fifty per cent of flour consumed in the country is bleached and treated by an organic peroxide. More flour is reclaimed than would otherwise be available for human consumption by this treatment. They are increasingly being consumed in the refining and bleaching of many of our edible oils."

Dr. Kokatnur prophesied a possible important rôle for these little-known compounds in developing a future liquid fuel supply. "There are many other outlets awaiting future exploitation but one of them provides a wonderful tool in the hands of a chemist for novel synthetic products. While they may not be cheap and commercially feasible in the immediate future the changed circumstances might make them very important. The present hectic efforts being made to replenish the gasoline supplies from other sources like coal cannot really solve the problem. Even the coal supplies cannot last forever and the only way to solve the problem is to fall on sources that are perennial and can be grown from the soil. Organic peroxides might then point the way to replenish the gasoline supplies from such perennial sources."—*Science Service*

CHEMISTRY IN RELATION TO NATIONAL DEFENSE*

EDWARD GREGG, LAS CRUCES UNION HIGH SCHOOL, LAS CRUCES, NEW MEXICO

Probably no other science is so comprehensive as chemistry. Its presence and influence are manifested in all fields of human endeavor; it has, in its short existence as a real science, fundamentally changed the very essence of human civilization. It has opened up vast spheres, new to the world, for the expenditure of human energy. It has already assumed gigantic proportions, with no conceivable limit to its possibilities. Even now, scarce out of its embryo, it holds a position analogous to that which venerable philosophy once held. Although in years to come prodigal offspring may forsake the parent, as was the case with philosophy, it is yet a well-defined and all-embracing subject.

EDWARD GREGG

But to do justice to all its countless phases, angles, and branches would necessitate a lifetime's sacrifice, great knowledge of the subject, and rare genius; and as this is to be a limited effort, let us choose and briefly review its manifold relations to a well-known pastime—mutual destruction.

War is immemorial, has been lauded by the poet, encouraged by the statesman, tolerated by the commoner, and firmly rooted in civilization by the militarist. Formerly it consisted of hand to hand engagements, brilliant strategy, and brute force; now it is fought out in laboratories and in chemists' minds. While generals and diplomats take credit for heroism, the striving researchers are denounced as enemies of the human race. Chemists are at the same time the odious and the indispensable ally of ambitious politicians.

Because in 1914 the science of chemistry was among the conscripts, and because it has taken frightful revenge for this coercion by becoming hopelessly entangled in the net of Mars, those concerned for the welfare of our nation have taken a deep interest in this profound and infinite subject. Our civilization is chemically built; our amazing twentieth

* Prize-winning high-school essay, 1927–28.

century progress is due to chemical research; and now our national integrity is to be based upon chemical initiative. No longer shall a patriotic mobilization to a sensational appeal save us. Gone is the day when peerless leaders can stem the tide alone. All are helpless without the chemist's aid. He alone cannot win, but he alone can maintain an impregnable national defense.

Nor does this gospel lack its exponent among the nations of the world. General Lefebre, in "The Riddle of the Rhine," emphatically states that between 1914–1918 there took place in warfare such radical changes as could not have been effected in a hundred years of previous peace! This zealous disciple of the cause goes on to say that initiative in electricity, chemistry, and other sciences will be the decisive factor of future warfare, and that disarmament and outlawry, by post-war sentiment, of certain pernicious substances will have no detrimental effect, due to inevitable monopolization of chemical resources. In short, the belligerent of the next great conflict who enjoys a chemical monopoly will vanquish his foes. Such an advantage had Germany in 1914, but she was pitted against a preponderant enemy, had no precedent, and failed to follow up her initial gas attack.

This was a mere contingency. No prophecy can be made in regard to the future, except that chemistry will maintain and end all major conflicts, leaving the instigation to temporal institutions. And we, the people of the United States, to keep the world safe for democracy, must fight fire with fire. Our chemical ingenuity is peerless, our natural resources in general surpass those of any other great powers, and our merchants are fully capable of competition with Europeans in the marts of world trade; but unless these all hang together, they and our vaunted civilization will all hang separately on gibbets erected by wiser nations. If our resources are judiciously expended, our mercantile genius heartily supported, then the dynamic chemist will joyfully undertake to mold these raw products into finished engines of destruction, or useful peace-time materials, as the case may be.

But a prophet is not without honor save in his own country. Was not the submarine, an American invention, first used by a foreign nation? Was not President Wilson's conception of a League of Nations repudiated in this Democracy to be accepted thankfully by Europeans? Has not many another inventor and theorist gone abroad for recognition? It is all too true; we are hopelessly human. Yet since human character and thought are so easily molded, it is very probable that the nine stitches in place of one are within the bounds of possibility. Let us hope some Demosthenes will rail and inveigh against public indifference. If the nation once senses its predicament, proper legislation and preparations will naturally result.

As has been said, the recent war gave an incredible impetus to chemical

development. Among the chemist's contributions to the art of war are some so predominant that they at once arrest our attention. Gas is the first to come to mind, and gas is undeniably the greatest, deadliest, most efficacious weapon ever contrived by human inventiveness. We are told that the battles of tomorrow will be limited in extent only by the bounds of nature herself. War will be waged on a grand scale, gas will permeate the vaults and vitiate the air of great cities, and airplanes, from invisible heights, will deluge populations with lethal substances. Let us hope, pray, and beseech that such a calamity will not be necessary to awaken interest. If this theme becomes ethereal, it is due entirely to the volatile nature of the next war. Moreover, because of the flexibility of the industry, the manufacture of poison gases cannot be curbed. Typical of this is the similarity between the dye and poison gas industries. With slight alterations in machinery and personnel, either can be changed to the other on almost an instant's notice. Likewise, since the nitrate industry presents two such different aspects, it would be ticklish diplomacy to proscribe its continuance for it might be easily extenuated on the grounds of economic necessity. All this points inevitably to the fact that we, to compete with foreign powers and to uphold our integrity, must develop a thriving peacetime industry which will turn to account in time of war, should offer incentive to enterprising chemists, and shall have to reserve and utilize such resources as will render us independent in time of a crisis. Nevertheless, we should not assume a hermit-like policy by erecting forbidding tariff walls, but, on the contrary, should cultivate a brisk commercial intercourse and endeavor to break up any monopoly held by another nation.

Even as we must reach out the national arm for the constituents of poison gases, so we must have a concern for sources of potential explosives. Nitrates, potash, and phosphates are of these requisites which invite American initiative. Found chiefly in far-off lands, in far-off lands they must be sought. Germany had control of these sources, and had not Britannia ruled the waves, the Iron Cross might even now embellish the earth. Our chemists as well as others can devise more violent, propellant, or deceptive explosives, but practical use calls for accessibility and large-scale economical production. As the chief use of explosives, and of the compounds from which they are prepared, is a peaceful one, a great industry can be amply justified. Pacifists will object, but no deluded minority should be allowed to hinder a constructive national program. We continue building battleships, an obsolescent department of the navy, which cost us millions of dollars to construct and operate, and which are a dead burden in time of peace, so why not maintain an industry practical in both peace and war. This would be the most effective means of disarmament and of ending suicidal army and naval competition among the

great rivals of the earth. In arguing the point, let us concede it a wrong and prove it the best means to an end. Then, if anyone can provide a better scheme, so much the better.

From the standpoint of its pristine motives, if there were any, the late European turmoil was a huge, terrible joke. New states were formed, old governments subverted, constitutions wrought and abolished, and society reversed; but the German ensign does not greet the four corners of the world, Britain was not exterminated, nor did she herself annihilate the Teutons, France is yet an integral republic, and the United States still flaunts democracy and dollar diplomacy in the face of the world. Despite its seeming futility, however, this great disturbance will probably be accounted by future generations as one of the greatest landmarks in all the history of mankind—ranking with the year one and the ice ages as a line demarcation between two vastly different epochs. This brief period of strife has revolutionized society the world over, and has been attended by the discovery and introduction of more new theories, facts, innovations, and mechanical devices than have been witnessed through any similar era in history. The fall of a dynasty or collapse of some institution is insignificant in the eyes of this great war. Things of more lasting effect and greater moment have been brought about. Seated firmly on one of the high peaks resulting from the late upheaval is aviation. Though the conquest of the air is a product of pre-war genius, it required this crucial test to stabilize and perfect it. The art has been made safe and numbered among Mars' most vicious tools by the recent war. Luckily, though, it is far from the burden incurred by armies and navies for it augurs well to become a most important means of commercial transit. It is yet in its infancy, however, and demands some patient guardian and tutor.

What better instructor than chemical science! Daring young pilots cannot give the airplane its proper place in domestic and bellicose spheres; it must be modified, shaped, improved, and instituted by government subsidy and chemical intuition. These two, in coöperation with the myriads of aeronautical aspirants, can realize the dreams of aviation's leading exponents and silence the Phillipics of certain editorialists. Chemists have produced in sufficient quantities the rare element helium for the navigation of lighter-than-air craft, making this a more feasible project. They have otherwise lent immeasurable aid in the perfection of these leviathans and have been prominent in the transition of aeronautics from a daredevil occupation of a foolhardy few to a safe, sane, and economic policy. And it is due to their activity that duralumin has made the winged squadron such an important unit in war.

Summing up the foregoing, if correct, it is safe to say that modern war consists of three major departments, *viz.:* the explosive, the gas, the aeronautical. Such are the great changes in warfare that individual engage-

ments will be classified as guerrilla tactics, cavalry will be confined to military parades, infantry will be effectual only in follow-up maneuvers, and strategists must think in terms of gas, aviation, and monster guns. Submarines and airplanes will relegate the gallant man-o'-war to story books, messengers of death from far above will threaten lives of "high moguls" formerly safe behind the lines, and the "Four Horsemen" will leave in their wake pestilence, famine, conquest, and death. Wholesale slaughter of defenseless women, children, and decrepits will become inevitable, with only the consolation of fixing the blame. After each active participant has deftly evaded the guilt, some wag will suggest the chemists. Yes, they have devised these hellish weapons! They are the abettors of crime and rapine! In vain will fair-minded men remind the people and their demagogues that chemistry was involuntarily drafted into the war, that usurping governments converted peaceful laboratories into bristling arsenals, and that the reluctant chemist's talents were forcefully prostituted on the altar of Mars.

As more pertinent to the subject, let us briefly inquire into our nation's chemical rank among the powers that be. Within an area larger than Augustus' empire, there is yet a vast virgin territory of incredible potentiality. Compared with the intensive exploitation of Europe's age-old land, our fair country seems merely scratched. Well-nigh inexhaustible chemical resources abound within our national confines, beckoning to the chemist's genius and the capitalist's foresight. If England were cut off from *her* colonial empire, she would be pitifully marooned on a barren rock, whereas *we*, in similar circumstances, would be securely ensconced in a veritable world of our own. Yet, though augmented by fabled Atlantis itself, our situation, destitute of chemical enterprise, would be as embarrassing as John Bull's. Once fully awake to the situation, sufficient capital backing a fruitful chemical industry, and that industry heartily approved, the gods of fortune are with us. The Utopian dream of leadership in peace and ascendency in war would be accomplished.

Discovers Chemical Properties of Virus. Important steps leading to a clearing up of the true nature of viruses that cause diseases like smallpox and chickenpox, have been made by Dr. E. V. Cowdry at the Rockefeller Institute for Medical Research. By making delicate micro-chemical examinations Dr. Cowdry has found that although the viruses of different diseases are distinct, the substances they form in the nucleus of cells, called "inclusion bodies," are alike. However, this does not mean that there is a corresponding similarity in the method of action of the viruses.

Significant among the results is the fact that iron, which is known to occur in detectable amounts in almost all living things, was absent from the inclusion bodies. This seems to disprove the theory that the inclusions are composed largely of micro-organisms, which cause the diseases.—*Science Service*

THE RELATION OF CHEMISTRY TO THE HOME*

SYLVIA SIMON, SENIOR HIGH SCHOOL, TRENTON, NEW JERSEY

Herbert B. Adams, head of the Department of History at Johns Hopkins, at one time said, "The home is the bedrock of human society." Until a child has reached the age of five, the only education which he receives is at home from his surroundings. This early environment makes a great impression on the child and helps to mold his character into what it will be in later years. And so it is all through life, the type of home silently but surely forms the characters of the great mass of young men and young women who are to determine the destiny of our great America. How much easier it is now to create that atmosphere of refinement and culture, so much desired in the home, than it was thirty or forty years ago! With all the resources that chemistry has put at its command, the United States bids fair to become the most cultured country in the world. We are so accustomed to the luxury and beauty of the American home that we do not realize that homes were not always as they are now.

SYLVIA SIMON

When my mother was young, she lived in a small Russian town. Her house was made of logs in the manner of Lincoln's home, while the roof was thatched with straw. The dwelling itself consisted of only one room which was partitioned into two small rooms by a huge fireplace extending through the middle. Of the two rooms, one was used as a bedchamber and the other as a kitchen, dining-room, and living-room. On the bare white-washed walls of the kitchen there were no ornaments except some shelves containing shining copper pots. This being before the days of Dutch Cleanser and steel wool, the pots had to be scoured and scrubbed with fine ashes and straw, then given a final polish with chalk. Suspended in rows were knives and forks made of wood. Fine sand obtained at a neighboring town was strewn over the floor. The bedroom had the same white-washed walls,

* Prize-winning high-school essay, 1927–28.

while the beds contained mattresses of straw. There was no sanitary bathroom as we have here, but wooden structures in the fields. A village well was the only source of water, and as a result of this lack of water, clothes had to be washed at a neighboring stream and beaten smooth with a stick. Because of the inconvenience of this method, clothes were laundered once every three or four weeks. Although some homes had kerosene lamps for light, most of the houses had arranged in the wall, splints, the burning of which gave light. On account of the danger of fire these burning splints had to be watched continually.

Contrast this home with any one of our homes here in America. A typical middle-class American home is a semi-detached dwelling made of red brick or hollow stones manufactured of chemically prepared cement. Instead of one room, these dwellings contain ten. Often there is a fireplace in the living-room; but what a different purpose it serves from that large one in the little home across the sea. The living-room itself presents a quiet, restful air brought about by the gentle, subdued colors which blend so perfectly. Beside the fireplace there is a bookcase containing books of interest to everyone in the family. The mohair divan gives one a luxurious feeling of comfort. Soft silk curtains drape the windows, either shutting out the glaring sun by day or giving one a sense of privacy and security by night. There are also a piano, a desk, and, on the walls, highly prized photographs. Some of the latter are reproductions of masterpieces, others, pictures of members of the family, while still others are exact reproductions of fine scenery. There is a beautiful rug covering the bright, waxed, hardwood floors. A cheerful room is the dining-room with its furniture and wall paper which adds just the right amount of color. The bay windows allow a flood of sunlight to find its way into the room, making it a healthy place in which to eat. However, it is the kitchen that presents the greatest number of improvements. A clean, white, enameled gas stove for cooking and a white porcelain sink with a supply of "pure" water convey to one a realization of the cleanliness of a modern kitchen. The walls are half white-tiled and half covered with gay wallpaper which blends with the table and chairs. Further evidence of cleanliness is the "inlaid" floor which can be easily washed. In the pantry cabinet stand rows of clean dishes, not wooden as in the little Russian home, but of chinaware; and knives and forks, not of wood, but of nickelware or beautiful silverware that will not corrode. Aluminum pots, a great boon to cooking, are also part of the equipment. Even the foods are attractive in the forms of fresh fruits, vegetables, and cereals, while a large refrigerator prevents dairy products and meats from spoiling. In the laundry are sanitary tubs and all the water necessary for laundering. Upstairs, the best thing is the sanitary bathroom. Its white-tiled floor and walls, its porcelain bathtub, lavatory, and wash-basin, as well as the shower, suggest comfort and sani-

tation. The bedrooms, furnished according to the individual tastes of the possessors, have beds containing soft, downy pillows and comfortable mattresses. But besides all this, the house contains what the people in that little home in Russia never dreamed of possessing—electric lights.

After comparing these two homes, one wonders what it was that brought about this wonderful change in so short a time. My study of chemistry in school shows me that it must have been this creative science. For is not chemistry the fundamental science of the transformation of matter?

Further study of the improvements greatly enlightens the mind as to the relation of chemistry to the home and makes one wish to believe that chemistry is the work of magicians rather than hard-working men. The red brick or the hollow cement stones of the modern dwelling were made by a chemical process. It was the chemist who discovered that clay containing a great deal of iron formed red bricks while that with little iron made cream-colored bricks. It was also the chemist who formulated the recipe for Portland cement. In the living-room, the gas-lighted fireplace was made possible by the discovery of methods of making cheap gas. The type of gas used in our home is water-gas. This is a mixture of hydrogen and other products formed when steam is passed over coal heated to incandescence. It is to the chemist we are indebted for colors present everywhere. What a great transformation chemists made in the world when the process of manufacturing synthetic dyes was discovered! Until then practically the only colors used were those obtainable from the indigo plant and madder-root, and only the nobility could afford a wealth of color in the home. With the creation of synthetic dyes, thousands of varieties of colors never before manufactured by man became accessible to everyone. The application of these colors has now become a science in itself. Our mohair living-room suite would not have been possible without the chemist. Chemistry was used in the preparation of the fibers and supplying finishes for the completed cloth, giving it its particular texture, while the dyes made possible the coloring. By the invention of the process of making artificial silk and the science of the application of dyes, we have our soft, beautiful draperies. Among all the triumphs of chemistry, probably none is more spectacular than that of the making of artificial silk. Count Chardonnet observed that, in spinning its cocoon, the silk worm ejected a semi-fluid substance which possessed the property of hardening immediately into silk. He found that by forcing collodion, which is nitro-cellulose dissolved in a solution of ether and alcohol, through a very fine capillary opening, he could obtain a substance from which the ether and alcohol evaporated leaving artificial silk fibers.

The piano and desk in the room were both made of wood varnished with chemically made products, and the beautiful rug was there because the

process of making fast colors had been discovered. It is likewise true that but for chemistry we would have no books in the home for purposes of recreation and education. Of course, there have always been hand-written books such as those compiled by the monks, but these were not for the benefit of the great mass of people. With the invention of paper from wood pulp, printer's ink from carbons, and fabrikoid from nitro-cellulose for the covering, books of moderate price have been placed on the market, and every home can have at least a small library of its own. The pictures on the wall, prints and photographs, all are dependent upon chemistry. In short, without chemistry, there would remain a bleak, colorless room devoid of all comfort.

In the dining-room the wallpaper is a combination of cellulose and synthetic dyes. Again, the bay windows which allow the light to penetrate are solely a triumph of chemistry expressed in the glass industry. Chemists, moreover, are not satisfied with the glass now used for window making but are working on glass-like quartz. Through the windows of today, many of the direct, health-giving rays of the sun are lost. Vitamin "D," a very essential principle, is said to be made in the bodies of animals under the influence of direct sunlight. Quartz will let in some of these rays, and chemists have already produced glass having the property of transmitting more of these rays.

Nowhere has chemistry taken a more prominent place in the household than in the kitchen. Sanitation prevails from the pretty but inexpensive "inlaid" to the porcelain sink into which runs pure water. Through the use of alum and chlorine the chemists have succeeded in supplying a means of giving a pure, healthful water to everyone whether he lives in city or country. The inlaid was produced by a chemical process which has made it cheap enough for every household. There is no excuse for dirt with the great varieties of cheap soaps, which are made from different materials discovered by chemistry to suit every purpose. The use of soap has changed from a luxury to an everyday necessity. The white porcelain of the sink was not made without the aid of science, and we now have "Dutch Cleanser," a chemical product with which to clean the sink. In the pantry there are evidences of chemistry everywhere. The chemistry of pottery has brought individual plates. Through the study of metallurgy, the chemistry of metals, have been discovered aluminum pots, invaluable to the housewife of today, because they are very light and will not rust like the old-fashioned copper pots. An additional factor is that they can be easily cleaned with "steel wool." The shelves stocked with wholesome foods show the work of the chemist in the family diet. Knowing that our bodies need a definite amount of vitamins, carbohydrates, and proteins, the chemist has shown the people the way to health by telling them what to eat. Fortunately for everyone, the milk can be kept cold

and free from disease bacteria by means of refrigeration dependent upon ammonia that is obtained from coal by the chemist.

Upstairs, the bedrooms with their mattresses in iron beds, proof against vermin; the bathroom with its equipment, and the medicine chest with the first-aid appliances that chemistry has given to medicine, and without which very few homes can be found, all testify to the great victories of chemistry.

I wonder if we fully appreciate all that chemistry has done for us? It has been said that chemistry is like the ghost in a classical drama, for, although we do not come in contact with it as frequently as with physicians, its influence is greatly felt. In every detail of our daily home life, we are dependent for our comfort, yes—for our very existence—on something that the chemist has created.

Chemists' Aid to Agriculture Nearing Century Mark. The official aid of chemical science to agriculture is almost a century old in this country. The first definitely datable publication in agricultural chemistry was an article by Dr. Benjamin Silliman on the improvement of sugar cane, in 1830, Dr. C. A. Browne of the U. S. Department of Agriculture told chemists meeting at the American Chemical Society Institute. Since that early date the activities of chemistry in agriculture have been numerous and ever-expanding, the speaker said. A prophecy made eighty years ago by the famous German chemist, Baron Justus von Liebig, that some day commercial fertilizers would be judged and priced according to the exact amounts of the chemical elements they contain, has been realized. The standardization he foresaw for farm chemicals has been carried further, first to cattle feeds and finally to human food as well, in the pure food legislation of the nation and the various states.

One of the most promising fields of activity in chemistry as applied to agriculture, Dr. Browne stated, is the transformation of farm products to meet the shifting demands of the market. "With the changing habits in food and dress of the American people, there is need of a readjustment in the uses which are made of agricultural products. The per capita consumption of meat and bread has diminished during the past quarter of a century while that of vegetables and sugar has increased. Changes in style have reduced the per capita demand for cotton in clothing. . .By devising improved methods of utilization, chemistry is now playing a rôle of increasing importance in creating new markets for agricultural products."—*Science Service*

All Life Needs Iron in Order to Breathe. Iron, long known as the stuff that is basically responsible for keeping the blood red, has now been shown to be equally responsible for the respiratory chemistry of all forms of life, according to M. L. Anson of the Rockefeller Institute for Medical Research.

The red pigment of the blood is the most familiar to us because it is such an intimate part of us, and small accidents enable us to see it oftener. This is hemoglobin. Hemoglobin is made up of two parts, a protein, globin, joined to a substance containing the iron and known as heme. Heme can be hitched up to a number of different protein compounds besides globin, and each such union provides a mechanism that can pick up and carry free oxygen and under appropriate circumstances release it again to some other living part of the organism. This makes possible a large number of different chemical means of respiration in living things, though all are based on the same iron-containing stuff, heme.—*Science Service*

CHEMISTRY AS APPLIED TO THE OIL FLOTATION OF COPPER ORES*

ESTHER LAINE, BISBEE HIGH SCHOOL, BISBEE, ARIZONA

Developing steadily through the centuries, the copper industry has changed from a crude practice into a complicated system of interwoven processes. Agricola, with his descriptions of crude metallurgical processes, could not vision upon what a stupendous scale our modern copper industry would be balanced. The force that has created this wonderful transformation is chemistry, the backbone of industry. Simple charcoal effected the first chemical change, causing the reduction of copper oxide:

ESTHER LAINE

$$2Cu_2O + C = 4Cu + CO_2.$$

From this modest beginning, the copper industry has become so complex and so important that we are fairly amazed at its extent. In our own United States, untold wealth has been made by the indispensable aid rendered the copper industry by chemistry. When the great copper camps in the West were established, only oxidized ores were smelted, while rich sulfide ores were left untouched. With the invention of pyritic smelting, however, these great sulfide deposits became valuable. In countless other ways, chemical science has improved the copper industry; she has made so many improvements in its production that today copper is the only raw material of importance that sells below pre-war prices. The story of copper is characterized by the constant presence of chemistry. From youth to age, copper is fostered by the chemist. Copper's metamorphosis from a greenish tinted ore into a beautiful reddish colored metal is the result of his work.

Chemistry has always solved the puzzles of industry. Yet, twenty years ago, it looked as if even chemistry could not combat a thing that seemed inevitable—the exhaustion of the copper supplies. At that time

* Prize-winning high-school essay, 1927–28.

it was thought that the copper supplies, the consumption of which was increasing sixty per cent each decade, would be exhausted within sixty years. Prospectors were no longer finding rich ore bodies. Those already found were, by the unceasing operations upon them, fast being exhausted. Yet there were huge porphyry mountains containing low-grade copper deposits. But these were worthless to metallurgists. No smelter could profitably smelt ore of such low grade. If this ore were to be treated in a smelter, the minute particles of copper sulfide which spotted the porphyry ore here and there would have to be put into a more suitable and concentrated form. Despite this perplexing situation, chemistry found a solution. This time the talisman it offered was the oil flotation process.

Let us take the Sacramento Hill project of the Phelps Dodge Corporation at Bisbee, Arizona, as one example of the many projects made possible by oil flotation. Before the discovery of this process, Sacramento Hill, although known to contain low-grade ore averaging 1.60% copper, was considered worthless. Now, however, Sacramento Hill is being mined in full force; and already it has dwindled into a deep pit. About the same amount of material has been removed from it as that removed from the famous Culebra cut of the Panama Canal.

The chemist not only made possible the profitable mining of this hill, but he also installed efficiency and economy in the mining itself. After the ore has been steam-shoveled into the ore cars, an employee prods off a sample. This sample is hurriedly taken to the chemist whose analysis determines the route to be taken by the ore cars. This analysis is very important, for each grade of ore requires a special treatment. If the sample shows 0.3% copper or below, the ore is sent to the waste dump; if 0.3 to 0.55%, to the number two leaching heap; if 0.55 to 0.8%, to the number one leaching heap; if 0.8 to 6.0%, to the concentrator; and if above 6.0%, to the smelter. Chemistry allows no waste of time. This analysis is quickly made; and before the ore-laden cars have reached the junction at which the railroad divides, the chemist has telephoned the train dispatcher who, by the information given him, switches the cars to the proper track. This may lead to the waste dump, the leaching heaps, the concentrator, or the smelter.

One of these destinations, the concentrator, is a great and successful experiment of the chemist. This concentrator is built upon the oil flotation principle and may be taken as an example. The ore arrives at the concentrator in fifty-ton side-dump cars. Each car is in turn rolled up beside an eight-inch grizzly. A whistle blows; a rod of the car disconnects; and with a deafening roar, the grayish colored ore tumbles over the grizzly. This marks the beginning of many processes which reduce the ore from boulders five and six feet in diameter to particles small enough to pass a 200-mesh screen, the fineness required by oil flotation. To accomplish

this reduction, a series of crushers, rod mills, and classifiers are used.

First, a succession of relentless crushers reduces the ore into pieces of $1^1/_4$-in. maximum. Then, the ore, to which lime and water have been added, enters rod mills. These are strongly built, barrel-shaped, steel rotators containing tons of steel rods. The rotation of the mill causes the steel rods to fall upon each other, thus grinding the ore into minute particles. For efficient operation, classifiers work in closed circuit with the rod mills. They prevent wasteful grinding of the undersized particles which they send directly to the pulp distributing box while sending the coarser sands back to the rod mills for further grinding. From the distributing box, the pulp flows into the flotation machine.

Here the true romance of the concentrator begins. Flotation is a process which can truly be said to have caused more heart palpitation than any other chemical or metallurgical wonder of the twentieth century. Litigations involving millions have been fought over flotation patent rights. Yet, to Mrs. Carrie Everson, who reaped no reward for the discovery that has earned millions for others, goes the credit for the true achievement. Through her work with her husband, she became interested in chemistry and metallurgy. By experimentation, she discovered the possibility of flotation; and in 1886, she took out a patent for the process.

Flotation is based on a strange phenomenon. The heavier mineral floats; the lighter gangue sinks. This paradox is caused by the judicious use of chemicals or reagents aided by air bubbles. Oils, by some strange attraction, coat the minerals, leaving untouched the gangue matter. But, as the chemist desires only the copper mineral and not the iron pyrite to be oiled, he adds a flotation controlling agent which causes the preferential filming of the copper mineral. Air bubbles introduced into the pulp show an affinity for the oiled, finely ground, copper particles which they elevate to the surface of the pulp. The undesirable iron pyrite and gangue matter are depressed to form the tailings; while millions of little bubbles bespeckled with copper mineral float off as a concentrate. This wonderful method of recovering the copper mineral was made possible only by the patient experimentation of chemists who discovered the process and who tested out and found the reagents which would bring about the desired flotation. In this mill, pine oil and potassium xanthate ($KS_2C_3H_5O$) are used as the flotation and flotation-controlling agents, respectively. The lime added at the rod mill serves as a reagent preventing any detrimental soluble matter from forming in the pulp.

The flotation machine is a long, oblong apparatus. The froth, carrying with it the valuable mineral, overflows on the sides of the machine. The first twelve to sixteen feet of the length of the machine holds a rich concentrate in the form of dark greenish colored froth. This is the finished concentrate; while the less valuable overflow of the remaining section is

pumped back into the flotation distributing box for redistribution. The flotation machine has two products, concentrates and tailings. The tailings, which contain only 0.22% copper, are sent to the tailings dams, while the concentrates are classified into two products: slime concentrate and sand concentrate.

To remove moisture, dewatering tanks take care of the sand concentrate while thickeners and filters dry the slime concentrate. After this treatment, the concentrates enter waiting cars. These carry their contents to the smelter—there to undergo numerous chemical changes and issue forth as "blister" copper, ready for the final refinement. Oil flotation has concentrated the copper from 9.26 tons of ore into one ton.

From this synopsis of the concentrator, we see how a complex assemblage of machines, dependent upon flotation, has come into existence through the work of the chemist. But his work did not stop here; it encompasses more. He is, in fact, the master of the mill, because the concentrator is a chemically controlled apparatus. All stages of grinding and the operation of the machines are controlled by knowledge gained from chemical analysis of the products. Head, tail, and concentrate samples are taken; and from the results of the assays of these, the superintendent knows exactly what extraction of copper has taken place. This shows the condition of the apparatus. A high percentage of copper in the tailings indicates the need of a change. Thus, if repairs are needed, the chemist will warn the mill man; if the process is unsatisfactory and a better method could be substituted, the chemist will submit his recommendations which will offset the trouble.

The flotation apparatus itself is the one upon which the scrutinizing eye of the chemist has been especially placed. The mill originally used the Callow flotation machine. However, the deficiencies of the machine caused poor recoveries which were detected by the chemist. The Forrester type was substituted. Even now, the MacIntosh flotation machine is being tried.

In the great 5000-ton concentrator of the Phelps Dodge Corporation at Bisbee, three sampling men, three assayers, and one or two testing engineers are employed while only six men operate the entire mill. These numbers show the importance of the chemist in the control of the mill.

When new reagents are tested as to their applicability to the ores, the chemists experiment in certain sections of the mill and there determine whether or not they are suitable. In these experiments, the chemist found that potassium xanthate could be used as a selective flotation reagent. Before this discovery, the use of gravity tables was necessary to further recover the copper lost in the tailings of the flotation machine. But as a result of the use of potassium xanthate, these tables which occupied an entire floor of the mill have been eliminated. This change in the flow sheet of

the mill has meant the elimination of all repair work on the tables and has effected a saving in the power cost of the mill. Moreover, where formerly eleven men were required with the use of gravity tables, only six operators are now needed.

Thus, by selective flotation, the chemist has advanced another step toward his goal, the perfection of every phase of flotation. However, one problem now confronts him. There are certain obstinate copper compounds which do not yield readily to flotation. Yet, with chemists delving into the mysteries of reagents, these compounds cannot long offer a barrier against the overwhelming powers of flotation. Some day this copper will be recovered from the enormous tailings dumps. Although there are innumerable organic substances, comparatively few have been tested out as flotation reagents. Preferential flotation offers vast possibilities.

With the constant finding of new reagents, the chemist is called upon again. Upon him rests the responsibility of determining the exact amount of reagents needed for each ton of ore. Although an error would be negligible for one ton, think of the waste it would involve if applied to the forty-one million tons of copper ore treated by flotation in the United States in 1925! Furthermore, an excessive amount of reagents adds to the floatability of the worthless gangue while an insufficient amount neglects some of the valuable mineral content. This determination is a very delicate responsibility ably shouldered by the chemist.

Thus, flotation is seen to involve a vast field of activities. Moreover, it has stimulated another great enterprise, leaching. With oil flotation taking out one grade of porphyry ore, the profitable treatment of still lower grade ore was made possible by the chemist's leaching process. As this process involves a slow gradual evolution of the ore into copper, its use would be unprofitable were it not that oil flotation made possible the extraction of the slightly richer ore. But now, with the mining of the porphyry ores, millions of tons of the less blessed ore are being sent to the leaching heaps. Here, through an enormous plateau-shaped mass of ore, water is spread; and in trickling down through this ore body, it leaches out the valuable copper content in the form of a sulfate solution. And this, carried by a miniature river flowing nearby, is pumped into a system of tanks filled with the waste iron of the city. Copper, by a chemical reaction, replaces the worthless iron and thus is recovered. The chemical reaction is represented by the equation:

$$Fe + CuSO_4 = FeSO_4 + Cu.$$

A million pounds of copper a month is extracted at a very low cost from ore which had long lain in the deep recesses of a mountain. Leaching, the beneficiary of oil flotation, is a product of the chemist.

Oil flotation, the worker of wonders, accounts for more than three-

fourths of the present copper production. Every American should have a special pride in this development because Americans designed the great concentrators in this country and in South America. An American firm has just moved its offices from Arizona to London to design and build concentrators and smelters in Russia, Africa, and India. Thus, American genius and capital, aided by chemistry, go to foreign countries as ambassadors of good will and dominate the copper industry throughout the world. In place of forts on foreign soil, America's monuments shall be structures of industry not to curse but to bless the world.

Bibliography

1. Personal interviews with Mr. Charles G. Wood, chemist and teacher, and the Messrs. Papin, Einneking, and Fugate of the Copper Queen Concentrator.
2. "The Story of Copper," Watson Davis.
3. "Wonders Worked by Selective Flotation," Gail Martin, *Compressed Air Magazine*, June, 1927.
4. "Consumption of Reagents Used in Flotation, 1925," Thomas Valrey.
5. Mining and Metallurgy, December, 1927.
6. Flow Sheet of the Copper Queen Concentrator, November, 1927.
7. "Present Status of Differential Flotation," A. W. Fahrenwald.

"Bios," Yeast Vitamin, Separated and Crystallized. "Bios," a substance that promotes growth in yeast as vitamins do in animals, has been demonstrated to be really two substances, and one of these two "bioses" has been prepared in pure crystalline form in the laboratory of Prof. W. Lash Miller of the University of Toronto. It proves to be a form of a seldom-studied but long-known chemical compound, inosite.

In 1901, long before vitamins were discovered, a Belgian chemist named Wildiers found that yeast needed for growth small quantities of some unknown substance which he could not isolate. He gave to this unknown material the name "bios," which is the Greek word for "life." After the discovery of vitamins, scientists began to take interest in this vitamin-like stuff needed by yeast, but it still defied separation and chemical analysis.

Then various researchers in Prof. Miller's laboratory began a systematic attack on the problem. One of them discovered that if a bios solution were shaken up with fine charcoal some of the bios vanished into the charcoal and what was left could not help yeast to grow. The part that was left could also be cleared out of the solution by other chemical means. This indicated that there was not one bios, but two; accordingly the names Bios I and Bios II came into use.

The latest advance has been to purify Bios I into crystal form. Crystals are the chemist's test for purity; a mixture will not crystallize. The crystals obtained have been analyzed and shown to contain the same proportions of carbon, hydrogen, and oxygen as common glucose, but the chemical arrangement is much more complex.

Bios I, or inosite as it has now been proved to be, is abundant in young, vigorously growing plant shoots. The German investigators who first studied inosite obtained their material from bean sprouts. The Canadian scientists who purified Bios I and established its chemical identity bought up large quantities of tea siftings for their raw material.—*Science Service*

ALFRED WERNER*

PAUL PFEIFFER, DIRECTOR OF THE CHEMICAL INSTITUTE OF THE UNIVERSITY OF BONN, BONN, GERMANY

Alfred Werner, son of a factory foreman, was born in Mülhausen, Alsace, on December 12, 1866. His predilection for chemistry became quite noticeable while he was still attending the lower schools, and when only

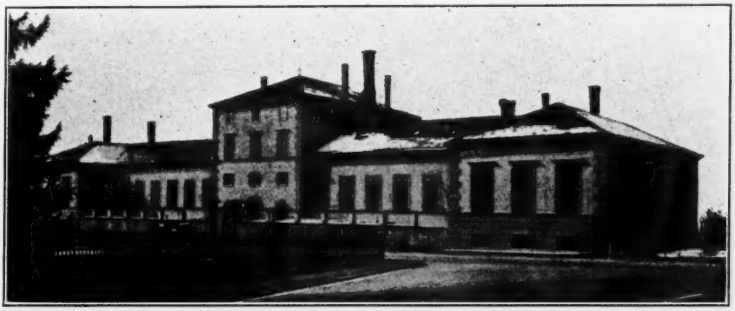
ALFRED WERNER

about eighteen he submitted for criticism the results of his first independent chemical investigation to Emilio Noelting, who was then director of the school of chemistry at Mülhausen. In 1885, Werner entered the army and

* Translated by Ralph E. Oesper, University of Cincinnati, Cincinnati, Ohio. The Prussian Academy of Sciences has generously authorized the publication of the translation of this biography. The original German text will appear in *Deutsches Biographisches Jahrbuch* 1917/20, Band II, Stuttgart, 1928.

served a term as one year volunteer at Karlsruhe and at the same time attended Engler's lectures on chemistry at the technical high school. The next year he moved to Zürich and in this city he made his home the rest of his life.

Three eminent chemists, Lunge, Hantzsch, and Treadwell were then teaching at the Eidgenossiches Polytecknikum (now called the Eidgenossiche Technische Hochschule) and they were responsible for Werner's excellent training. After receiving his diploma as technical chemist, 1889, he became assistant to Lunge; and at the same time, as co-worker with Hantzsch, began the study of purely scientific problems. His doctorate thesis, "On the Spatial Arrangement of the Atoms in Nitrogen Compounds," was accepted by the University of Zürich in 1890. Werner then spent one semester in Paris studying with Berthelot at the Collége de France. On his return to Zürich, he applied for a license to teach at the Poly-



THE OLD CHEMISTRY LABORATORY OF THE UNIVERSITY OF ZÜRICH

tecknikum, submitting with his application a dissertation, "Contributions to the Theory of Affinity and Valence." In this he disposed of many traditional notions and laid the foundations of a new valence theory. In the autumn of 1892, when only 26, he published "A Contribution to the Constitution of Inorganic Compounds," a paper which later became quite famous, for it marks its author as the founder of the modern views in this field and insures to him a rank in the history of chemical thought equal to that of August Kekulé.

Only one year later, in the fall of 1893, he was appointed successor of Viktor Merz, becoming extraordinary professor of chemistry and director of chemical laboratory *A* at the University of Zürich. Two years later he was promoted to a full professorship. He soon became one of the best known and most highly respected teachers and investigators at the University. Flattering offers from Vienna (1899), Basle (1902), the Eidg. Technische Hochschule (1905), and Würzburg (1910) were declined.

Honorary doctorates were conferred on him by the University of Geneva and the Technical High School in Zürich. He was elected honorary or corresponding member of numerous scientific societies. Among the latter were the Königliche Gesellschaft der Wissenschaften in Göttingen; the physikalisch-medizinsche Sozietät in Erlangen; the physikalischer Verein in Frankfurt; the Societé de physique et d'histoire naturelle in Geneva; the Societé imperiale des amis d'histoire naturelle, d'anthropologie et d'ethnographie in Moscow; Chemical Society of London, etc. The Swiss Chemical Society honored him by establishing a Werner Fund and also issued a Werner plaquette.

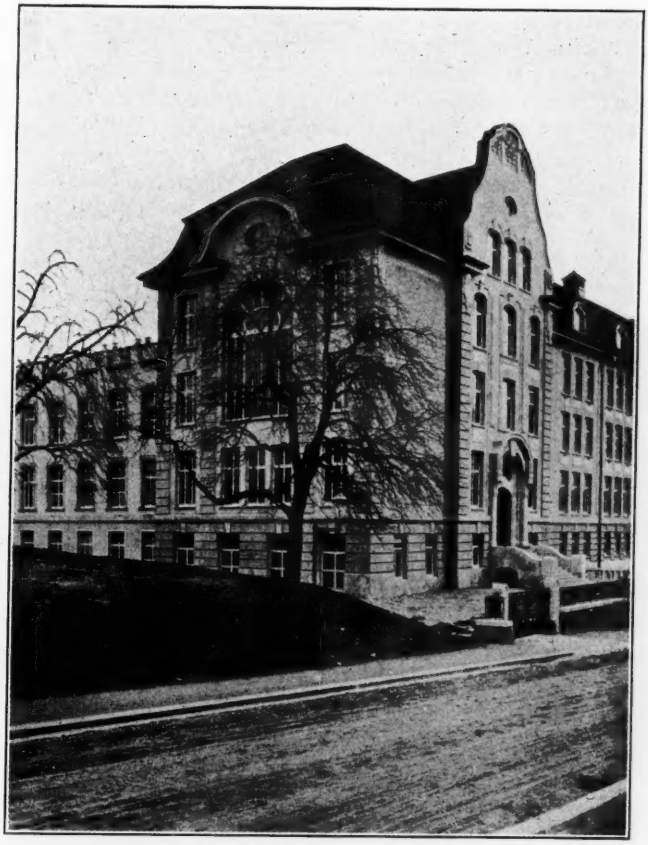
The highest scientific honor, the Nobel Prize, was awarded to him in 1913, and this occasioned a most enthusiastic ovation to their master by his students at Zürich. Even at this time, a serious disorder, arteriosclerosis, was beginning to make its destructive action evident, and at the end of 1915 he no longer felt able to deliver the general lectures. He resumed these at intervals but never for long, and finally the progress of the disease compelled him to relinquish his professorship in 1919. On November 15, 1919, death released this brilliant investigator, not yet fifty-three, from his distressing illness. He died while mentally deranged.

Werner was a plain, sincere character, possessed of a simple, candid disposition and endowed with high intelligence and firm determination. With a prodigious capacity for work and an endurance that seemed almost inexhaustible, he persisted at his theoretical and experimental problems, overcoming all human and material obstacles until he had reached his goal. It is obvious then that Werner was not an easy taskmaster to those working under his direction; his demands on them seemed often to reach the limits of possibility. However, this strict training has certainly been a great asset to many of his pupils throughout their entire lives.

Especially in his younger years, Werner made it a practice to discuss the newer work appearing in the literature or his own investigations for hours with his assistants and he demanded that sharp criticism be exercised during these sessions. His assistants did not always find it easy to follow the trend of his thoughts, for he had a fabulous memory which extended over the whole field of chemistry, both inorganic and organic, and he could pass from one subject to another with great facility. If the topic chanced to be, say, the isomerism of inorganic complex compounds, the discussion in a few moments would very likely be centered around analogous phenomena exhibited by terpenes, alkaloids, or dyestuffs. He insisted that his auditors have clear knowledge of the constitution and configuration of the individual compounds and be able to work freely with these concepts. He personally found no difficulty in these fields as he had a remarkable faculty for envisaging spatial relationships.

Under circumstances more favorable than those obtaining at Zürich,

this eminent investigator would doubtless have established a large school of chemical thought. Nevertheless, his Zürich laboratory produced numerous men who occupy prominent places in the chemical industries



THE NEW CHEMISTRY INSTITUTE OF THE UNIVERSITY OF ZÜRICH

and a goodly number of eminent teachers. Among these are Berl, Dilthey, Dubsky, Jantsch, Karrer, Pfeiffer, Schaarschmidt, and Stiasny.

He lectured only on organic chemistry until 1902 when he also took over the inorganic division. His lectures were well prepared, original in the arrangement of the material, and characterized by the clarity with which even the most complicated problems were treated. His delivery was

convincing, and he exhibited such enthusiasm for his science that his hearers were carried with him.

His teaching abilities were also evidenced by his two principal books, of which the more important is "New Ideas in Inorganic Chemistry." In this he has examined critically a vast mass of scattered data which were then, for the first time, classified systematically by means of his coördination theories. His "Stereochemistry" was also of fundamental importance, for it was the first comprehensive, critical treatment of this important field. Even present-day investigators of stereochemical problems find it necessary to refer repeatedly to Werner's text.

Werner developed a personal technic for his experimental researches on inorganic complex compounds. On his laboratory table stood several

VIEW OF THE CATACOMBS

micro-burners and micro-filter supports, together with several hundreds of small glass dishes, whose contents were of all colors. Although none of these dishes were labelled, he was quite sure that confusion was almost an impossibility. The laboratory in which he did his first work consisted of very inadequate rooms, those in the basement well deserving their popular designation, "the catacombs." In 1909, he had the pleasure of moving into a spacious new laboratory built from his own plans. From this issued, in particular, his important researches on optically active inorganic compounds.

Werner's wife, neé Emma Giesker, a native of Zürich, was a member of an immigrant German family. He also showed great affection for his children, one boy and one girl. He was a very sociable soul, finding recreation from mental toil among his friends in billiards, chess, or a Swiss

card game, jass. A few weeks of the fall vacation were usually spent in the mountains; he did not enjoy longer pleasure trips. He was an ardent attendant of scientific conventions, and frequently lectured in foreign countries.

As a native of Alsace, Werner's cultural sympathies were both French and German, but he always emphasized that German science was responsible for his professional training. Of his teachers he especially revered Arthur Hantzsch. His published articles almost without exception appeared in German journals, and his books were also written in that language. However, his sympathies were with France during the great war.

Even the first of Werner's scientific papers, his doctorate thesis, written at the age of twenty-four, is of considerable importance since in it he laid the foundations of a new chapter of stereochemistry; namely, of nitrogen. Although published in the "Berichte" under the names of Hantzsch and Werner, the latter alone is responsible for the fundamental idea; *viz.*, that in the numerous compounds of trivalent nitrogen (oximes, etc.), the three valence bonds of the nitrogen atom are directed toward three corners of a tetrahedron, whose fourth corner is occupied by the nitrogen atom itself. In this article, Werner successfully combated the views of V. Meyer and K. Auwers who sought to explain the isomerism of the benzil oximes by denying in this case the validity of the van't Hoff principle of the free rotation of singly bound carbon atoms about the C—C axis. His excellent extension of the van't Hoff theory of the stereochemistry of carbon has been substantiated throughout. The experimental development of his new views is due especially to Hantzsch, as Werner's participation was not for long. Problems of an entirely different kind soon absorbed his interest.

Only a year after the appearance of his "Stereochemistry of Nitrogen," his habilitation essay, "Contribution to the Theory of Affinity and Valence," was published in 1891 in the *Viertel jahresschrite der Züricher Naturforschende Gesellschaft,* and because of the limited circulation of this periodical the new ideas were only tardily recognized. This paper was a forerunner of Werner's masterly coördination theory. In this paper of 1891, he pursues a totally new path; he rejects the usual concept of valence as a directed single force; and assumes that affinity is an attractive force originating at the center of the atom and acting uniformly toward all parts of the surface. (For the sake of simplicity, the atom was imagined to be spherical.) Valency for him, then, became an empirical number concept. He succeeded in deriving the van't Hoff configuration formulas without assuming directed single forces; he worked out an acceptable interpretation of stereochemical rearrangements, and attacked the benzene problem from a new angle. These ideas were developed at greater length in 1906 in a paper, "The Variable Affinity of Simple Compounds," and in

conjunction with Thiele's theory of partial valence have been extremely fruitful for organic chemistry.

Werner's greatest achievement was without doubt the establishment of the coördination theory, with whose aid the young investigator, only twenty-six, cleared the way for a new phase of development of inorganic chemistry. According to his own statement, the inspiration came to him like a flash. One morning at two o'clock he awoke with a start; the long-sought solution of this problem had lodged in his brain. He arose from his bed and by five o'clock in the afternoon the essential points of the coördination theory were achieved.[1]

The significance of Werner's coördination theory may be better appreciated if it is pointed out that chemical compounds are conveniently classified as of the first order and as of higher orders (molecular compounds). As compounds of the first order are considered all those whose molecules are made up of two distinct atomic species (chlorides, oxides, sulfides, nitrides, hydrides, etc.). In this class are also placed those substances which are derived from these simplest compounds of the first order by replacement of single atoms by either atoms of another species or by groups of atoms (radicals). This includes the vast majority of the almost inconceivably large number of organic compounds. The Kekulé valence theory has proved absolutely essential in systematizing all these materials; its success is a veritable triumph.

Werner rejects the application of the Kekulé valence theory to molecular compounds, and to a certain extent he places them in a separate category, developing a new theoretical basis which permits of an orderly, comprehensive arrangement of even these compounds and, furthermore, his assumptions lead to a simple explanation of numerous cases of isomerism exhibited by these substances.

According to Werner's hypothesis, inorganic molecular compounds contain single atoms which function as central nuclei, around which are arranged in simple, spatial geometrical patterns a definite number of other atoms, radicals, or other molecules capable of independent existence. The figure expressing the number of atoms grouped around one central atom of a molecular compound was designated by Werner as the coördination number of this atom. The concept of coördination number, to which are also joined the concepts of "auxiliary valence number and force" and "indirect linking," forms the central point of the Wernerian system. Only a few coördination numbers come into consideration, the most important being 3, 4, 6, and 8. The number six occurs especially often. Thousands of molecular compounds of cobalt, chromium, platinum, etc., correspond to the 6 type. In all of these, as Werner pointed out in

[1] In this connection, see the article on Werner in the *Schweizerische Chemikerzeitung* for 1920.

his first paper, the spatial configuration is octahedral in that around the central metal atom lie the six coördinated atoms in the corners of an octahedron.

This mode of representation was so novel and departed so widely from all previous proposals that only a few of Werner's fellow chemists recognized the import of his ideas. The chief obstacle was the "organic" orientation of the majority of the chemists of that time, for that branch of the science was then experiencing great triumphs. Werner now entered upon a twenty-year period of experimental work, whose intensity has hardly ever been equaled. He and his co-workers constantly prepared new series of molecular compounds and studied their constitutions and configurations. More than 200 dissertations were produced under his direction; his own publications exceed 150. The structure of the chemistry of inorganic complexes revealed itself in more and more harmonious form and finally, after 18 years, he made the important discovery of the optically active inorganic compounds, whose existence he had foreseen from his octahedral hypothesis. This constituted the experimental proof of one of the most important deductions of his theory, and in consequence the great significance of the coördination theory for chemical systematics was generally recognized.

Now began the triumphant march of the coördination theory, but its author could no longer take an active part in its progress. Starting from a study of the metal-ammonia salts and of the double salts, two classes of materials which were then not considered of particular importance or interest, this theory, while still under Werner's guidance, embraced almost the whole of systematic, inorganic chemistry and its tentacles extended into the organic field, where today its importance is commonly acknowledged. Coördination concepts are playing an increasingly important rôle in crystallography, for it appears that, in general, crystals are built up in conformity with these teachings. If, in addition, it is assumed that these same considerations are valid in the theory of adsorption and of solution—though all this is still in the course of development—the comprehensive significance of Werner's life work follows as a matter of course.

Particular interest attaches to the question as to whether Werner's train of ideas was the culmination of a lengthy logical series of developments; *i. e.*, whether it is possible to name certain individuals who had preceded him in more or less clearly recognizing essential portions of his theories. In the writer's opinion, this is not the case. Of course, in formulating his coördination theory, Werner employed certain ideas arising from Kekulé's valence theories, from van't Hoff's stereochemistry, and from the electrolytic dissociation theory of Arrhenius. The structure of his teachings appears, however, to have been erected as an entirely independent creation.

This becomes especially evident if Werner is compared with Jörgensen, to whom (preceding and contemporaneous with Werner) is due credit for fundamental studies of the metal-ammonia salts. Jörgensen did not wish to break away from the usual inflexible valence theories; his formulas could not give lasting satisfaction, for they aroused no incentive to a further development of chemistry. Furthermore, Jörgensen was not sufficiently informed regarding the inner, theoretical, and experimental relationship of all the various classes of molecular compounds.

Mendelejeff was perfectly aware of this inherent connection. In his text "Foundations of Chemistry," which Werner knew in its German translation, he clearly emphasized the constitutional similarity of metal-ammonia salts, hydrates, and double salts; indeed he also included alloys and solutions in his discussion. However, his attempts to bring order out of this chaos were not successful, although he did demonstrate that the pure valence formulations then in vogue could not be maintained. He was also correct in his systematic placement of certain series of compounds, such as polymeric metal halides, Al_2X_6, etc. (which he considered as double halides). The privilege of reaching the goal toward which Mendelejeff had turned his thoughts was reserved for Alfred Werner, whose creation of the general coördination theory was the work of a genius.

BIOGRAPHIES PREVIOUSLY PUBLISHED

Karrer, P., *Helvetica Chimica Acta*, **3,** 196 (1920). Männer der Technik, 1925, p. 290, Herausgeber C. Matschoss; *Schweizerische Chemikerzeitung*, p. 73, **1920.**

Pfeiffer, P., *Zeitschrift für angewandte Chemie*, **33,** 37 (1920).

Lifschitz, J., *Zeitschrift für Elektrochemie*, **26,** 514 (1920).

Morgan, G. T., *J. Chem. Soc.* (London), **117,** 1639 (1920).

A practically complete bibliography of Werner's publications may be found in *Helvetica Chimica Acta*, **3,** 225 (1920).

Firefly Light Like Common Fire, but Cold. The fireflies, or "lightning-bugs," that dance in the air over twilight lawns carry torches that burn on exactly the same principle as a lighted candle. That is, they combine a combustible substance with oxygen and produce light. The great advantage the firefly has unconsciously worked out over man-made illuminants is that his tail-light makes so little heat that it can fairly be called a "cold light."

The shining of fireflies, and of other animals and plants, used to be called "phosphorescence," because it looks like the light given off by a bit of rubbed phosphorus in the dark. That, however, is a misnomer, for it is not caused by phosphorus. The basis of the light is a substance called "luciferin," which means "light-bearer." By itself it does not glow, but a second substance known as "luciferase," present in all luminous organisms, causes it to combine with oxygen, and this makes the luminescence. A further chemical reaction breaks the luciferase away from the combination, permitting it to be used over again an indefinite number of times.—*Science Service*

QUANTITATIVE ORGANIC MICROANALYSIS*

RALPH T. K. CORNWELL, UNIVERSITY OF PITTSBURGH, PITTSBURGH, PENNSYLVANIA

Chamot and Mason[1] in the last of the series of three articles which they published recently in THIS JOURNAL, distinguish between Chemical Microscopy and Microchemical Methods. Since it is important to maintain the same distinction in this paper, the following sentences are quoted from their article.

> Chemical Microscopy..... implies the use of the microscope in the process of examination or analysis. Such an examination may or may not require the application of a "chemical" reaction for the solution of the problem..... When a compound is identified by its optic constants and physical characters under the microscope without the use of reagents of any sort we are applying chemical microscopy.....
>
> ..... there has crept into general use the term "microchemical" to designate either supersensitive qualitative reactions or quantitative methods designed to be applicable to the analysis of amounts of material so small as to preclude the employment of the so-called standard or "orthodox" methods. Microchemical analyses may be made with the unassisted eye—no magnification by means of lens combinations being necessarily employed.

Chamot and Mason discussed Chemical Microscopy. The present paper deals with one phase of the Microchemical Methods—*Quantitative Organic Microanalysis*—which is simply the quantitative analysis of minute amounts (milligrams) of organic substances. Since the microscope is not used, the term "Milligram Analysis" has been suggested to avoid confusion but it has not been adopted.

"Chemistry took its origin out of knowledge of small mysteries."[2] The epoch-making discovery of Wöhler, that organic compounds could be made in the laboratory without the aid of any life process, unexpectedly developed from one of the smallest of these mysteries. In 1824,[3] Wöhler, in one of his studies of cyanic acid, isolated five milligrams of an organic substance. However, he could not identify this substance and recorded that it was *too small an amount for an exact investigation*. The experiment was repeated in an effort to get more of the material without success. The next year in another research,[4] he obtained a small amount of the same substance, but again not enough for a satisfactory study. Fortunately, he later found that this compound could be made in large amounts from

* Read at the A. C. S. Institute of Chemistry, Northwestern University, Evanston, Ill., August 2, 1928.

[1] E. M. Chamot and C. Mason, "Chemical Microscopy," THIS JOURNAL, **5**, 536 (May, 1928).

[2] E. R. Weidlein, "Value of Organized Scientific Research," *Proceedings of the Institute of Management*, No. **6**.

[3] F. Wöhler, "Analytische Versuche über die Cyansäure," *Annalen der Physik und Chemie*, **1**, 117 (1824).

[4] F. Wöhler, "Ueber Cyan-Verbindungen," *Ibid.*, **3**, 177 (1825).

silver cyanate and ammonium chloride or from lead cyanate and ammonium hydroxide. Then he was able to identify it as urea and, in 1828,[5] he published the paper which was destined to mark the beginning of a new trend of thought in the science of chemistry and allied fields.

Let us permit our minds to wander and imagine how Wöhler would have attacked the original five milligrams of material with the methods at the disposal of chemists today. Urea was a well-known substance in 1824 and, if Chemical Microscopy had been developed, the small amount of substance obtained by Wöhler in 1824 could have been identified under the microscope. Then, if Wöhler had so desired, he could have confirmed his microscopical results with a quantitative microanalysis. Five milligrams is sufficient for a molecular weight determination by the elevation of the boiling-point method. The material could have been recovered and from 1–3 mg. used for a carbon and hydrogen determination, and the rest for a nitrogen determination. The time required for these determinations, assuming that the apparatus was ready and the technic mastered, would have been about a half day. Thus, working a century later, Wöhler could have announced his important discovery after a careful investigation of only five milligrams of material. Indeed, it is safe to assume that Wöhler would have done so, since he determined and recorded two characteristic chemical reactions of the minute amount of substance originally obtained in 1824.

However, quantitative organic analysis was not easy in 1824 and it might be in place to note a few of the developments[6] in this phase of analytical chemistry. Quantitative Organic Analysis was created by Lavoisier, who was the first to determine the composition of an organic substance from the products of combustion. In 1781, Lavoisier determined the amount of carbon in carbon dioxide and, repeating the work of Cavendish, he also determined the hydrogen content of water. Then, in 1784, he utilized these facts to establish the constitution of organic substances. In brief, the procedure which Lavoisier developed follows. The organic substance was burned, using either tinder or a lens, in a measured volume of oxygen in a bell jar over mercury. The carbon dioxide formed was absorbed in a solution of alkali and determined by volume difference. The water formed was computed from the volume of oxygen consumed. The undecomposed sample was weighed and the necessary corrections made. This method, with some modifications, was used until 1814–1817, when Berzelius determined the water formed by absorbing it in calcium chloride and the carbon dioxide formed by absorbing it in solid potassium hydroxide.

[5] F. Wöhler, "Ueber Künstliche Bildung des Harnstoffs," *Ibid.*, **12**, 253 (1828).

[6] R. Cornubert, "La Microanalyses Organique Quantitative," *Revue Generale Science*, **33**, 203 (1922); J. V. Dubsky, "Quantitative Organische Mikroanalyse," *Chem. Weekblad.*, **16**, 1482 (1919); C. Weygard, "Die Entwicklung der organische Elementaranalyse von Lavoisier bis Pregl," *Z. für angewandte Chem.*, **38**, 881 (1925).

This was the beginning of the modern method of combustion analysis, burning the substance in a horizontal tube in an excess of oxygen or air and absorbing the products of combustion in suitable materials. Not until 1831, more than fifteen years later, did Liebig introduce his potash bulb for the absorption of the carbon dioxide, which completed the combustion method still commonly used. Berzelius writes of Liebig's improvement: "wir benutzen täglich Liebigs Apparat. Er ist ein herrliches Instrument." Meanwhile, about 1815, Gay-Lussac, with Thénard, and Döbereiner used copper oxide in the combustion tube. In 1831, J. B. Dumas published the simple direct method for determining nitrogen which is still used. So we see that, about the year 1830, the foundation of quantitative organic analysis was practically completed and but little change in principle has been made since that time. As far back as 1813, Berzelius had satisfactorily analyzed as small an amount as 0.335 g. of sublimed benzoic acid.[6]

In view of the important rôle which elementary analysis played in the development of organic chemistry, it is worthy of note that for almost a century attempts were not made to refine the methods of analysis so that the chemical constitution of the minute amounts of organic substances, so often obtained as by-products of reactions or met with in the living world, could be determined. Too often these important substances had to be recorded as of unknown constitution and in many cases were probably discarded without any record being made of them. Often experimental conditions were varied in an attempt to get enough of the substance for analysis. However, this was not always possible, particularly in the biological fields. Hence, organic chemistry has often been called the chemistry of the main products of a reaction.

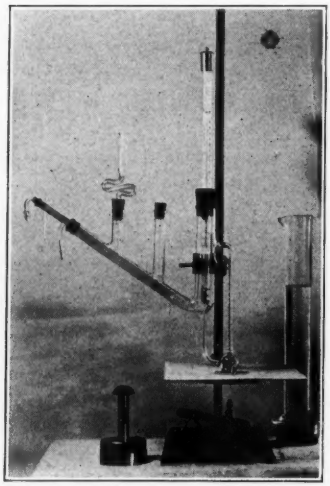
How much more would be known today about organic reactions that take place in the test tube or in the living cell, if successful attempts had been made earlier to refine the methods of analysis so that these small amounts of organic compounds might be investigated?

It was not until 1910 that serious efforts were made to refine the methods so that a few milligrams of an organic substance might be analyzed The work was started and successfully carried out by Professor Fritz Pregl, first at the University in Innsbruck, Austria, and after 1913 at the University in Graz, Austria. His work marks the close of the first and the beginning of the second chapter in the history of Quantitative Organic Analysis. In the summer of 1910, after a lengthy investigation of one of the acids found in the bile, Professor Pregl[7] obtained as a fission product a very small amount of an unknown organic substance. It was necessary to determine the constitution of this substance. Two paths presented themselves. Either he would have to spend a year repeating

[7] Fritz Pregl, "Quantitative Organic Microanalysis," translated by Ernest Fyleman.

the work with unusually large amounts of starting materials or methods would have to be devised to study the small amount of material that he had.

Struck by the success which Emich[8] and his collaborators were having in the investigations of minute amounts of material, Professor Pregl selected the latter path and started to refine the methods of analysis and to develop the technic necessary for the analysis of the small amount of material which he had. At first he was chiefly interested in determining carbon, hydrogen, and nitrogen. By 1911, the problem was essentially solved and it was possible to determine carbon and hydrogen in from 7 to 13 mg. of substance even in the presence of nitrogen and sulfur; to determine nitrogen in from 4 to 8 mg. of substance; and to determine sulfur and halogens by the Carius method in from 4 to 8 mg. of substance. This work was first made public[9] in a lecture given before the German Chemical Society in Berlin on February 27, 1911.



APPARATUS FOR MOLECULAR WEIGHT DETERMINATIONS

Encouraged by the results, he continued the work with the aid of his assistants and collaborators. By the end of 1913, the method for the determination of carbon and hydrogen had been improved so that the sample required could be reduced to less than 2 mg. The Carius method for determining sulfur and halogens was abandoned and replaced by the Köpfer-Dennstedt method of burning the substance in an atmosphere of oxygen in contact with platinum. The method for determining the molecular weight by the elevation of the boiling point was worked out; the determination of copper electrolytically was developed; the method for methoxyl determinations devised; and a beginning made in the method for the determination of methyl attached to nitrogen.

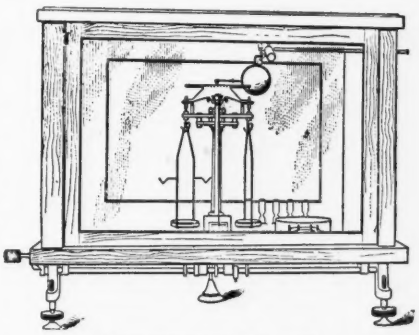
Dr. Dubsky,[9] who worked with Pregl and who has played an independent rôle in the development of organic microanalysis states: "On first glance the complicated work of an organic microanalysis seemed completely hopeless, and we have only the iron patience of the ingenious investigator to thank that all of the numerous, seemingly insurmountable difficulties

[8] F. Emich, "Ueber Mikrochemie," *Berichte*, **43**, 10 (1910).

[9] J. V. Dubksy, "Die Quantitative Mikroelementaranalyse nach Pregl," *Chem.-Ztg.*, **38**, 505–10 (1914).

could be overcome in two years of irksome work and ingenious, simple methods made public."

The most important piece of apparatus is the microchemical balance, the history[10] of which cannot be taken up here. The microchemical balance was constructed by Kuhlmann of Hamburg, according to the specifications of Professor Pregl. The necessary absorption tubes, filter tubes, boats, and other pieces of apparatus can be easily and quickly weighed on the balance. It will weigh a maximum load of 20 grams with an accuracy of ±0.001 mg. A balance[11] with the same sensitiveness is described in a price list of Paul Bunge published about 1880. Kuhlmann had for some time managed the works of Paul Bunge and is an expert in the manufacture of fine instruments. He was therefore prepared to meet the demands of Pregl.



MICROCHEMICAL BALANCE

To show the extent with which Professor Pregl covered the field successfully, the following list is given of the determinations which are described in the last edition of his book—"Quantitative Organic Microanalysis"—carbon and hydrogen, nitrogen (micro-Dumas and micro-Kjeldahl), halogens and sulfur, phosphorus, arsenic, metals in salts, copper (micro-electro-analysis), carboxyl, methoxyl, methyl attached to nitrogen, and molecular weight. Meanwhile, Professor Pregl and others have devised micro methods for many other analytical determinations, so that today practically any quantitative determination in the field of Organic Chemistry may be made using a sample of a few milligrams. A quantitative analysis can now be made on amounts of material which formerly sufficed only for qualitative tests.

In 1923, Professor Pregl was awarded the Nobel Prize in Chemistry. His laboratory has been and still is the Mecca for students from all quarters of the globe. There, in the charming old-world city of Graz, he receives them graciously and teaches them gratis the use of his methods.

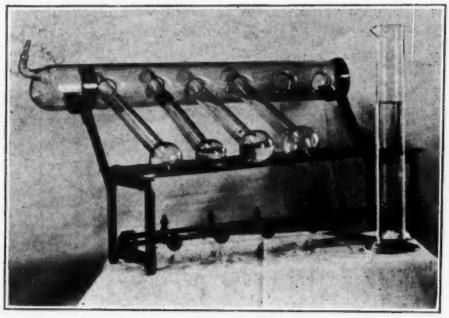
The world-wide use of the methods of quantitative organic microanalysis

[10] R. Cornubert, "La Microanalyse Organique Quantitative," *Rev. gen. sci.*, **31**, 442 (1920); F. Emich, "Ueber Mikrowagen und ihre Anwendung in der chemischen Analyse," *Die Naturwissenschaften*, **3**, 693 (1915).

[11] L. Dede, "Wer ist der Erfinder der Mikrowage?" *Z. für angewandte Chem.*, **37**, 166 (1924).

was hindered by the great war, although considerable progress was made in Austria and Germany. The chief difficulty, which persisted for some time after the War, was in getting a suitable microchemical balance. In our own country Dr. L. E. Wise,[12] in 1917, demonstrated that by using samples of from 8 to 13 mg. a sensitive analytical balance could be used for micro-combustions. However, this is no longer a question since good micro-chemical balances are now made in this country.

It is not the purpose of this paper to go into details regarding the experimental procedure. No new theory is involved, simply a refinement of apparatus and technic. Some of the apparatus is shown in the illustrations. Neither can the work of the many investigators, who, either in collaboration with Professor Pregl or independently, aided in the development of organic microanalysis, be considered. Much work is being done today in the improvement of the micro methods and in devising new ones. Developed originally to complete a biological investigation, the methods of quantitative organic microanalysis have been of great value in that field. Much important work in biochemistry, since 1910, has been made possible by the microchemical methods. Small mysteries still puzzle the scientist and as one thinks of the work yet to be done on the chemical constitution of enzymes, hormones, vitamins and other substances which occur in minute amounts and which are so vitally important, the value of the microchemical methods need not be emphasized.

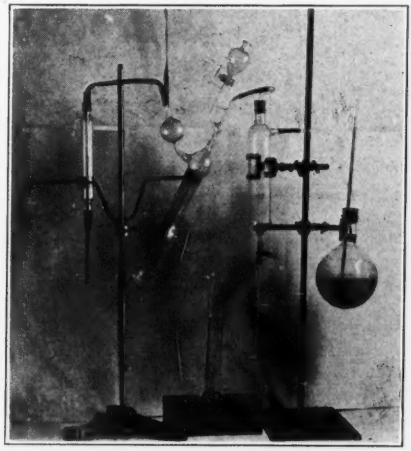


MICRO-KJELDAHL FLASKS
The 100-cc. graduated cylinder in this and the preceding picture is to give an idea of the size of the apparatus.

Moreover, it was soon noticed that the methods of organic microanalysis were of value regardless of the amount of material available. As the amount of the sample necessary for the analysis was decreased the time for the analysis decreased. A carbon and hydrogen determination can be made in from 50 to 60 minutes; a nitrogen determination, micro-Dumas, can be made in from one to one and a half hours; the time for a micro-Kjeldahl nitrogen determination is less than half of that required for the macro-Kjeldahl determination. The directions usually given for a halogen determination by the Carius method state that the substance is to be heated with the proper chemicals in a sealed tube in a bomb furnace for six or

[12] L. E. Wise, "A Simplified Micro-Combustion," *J. Am. Chem. Soc.*, **39**, 2055 (1917).

eight hours until the sample is completely oxidized. Using the micro method, as described by Professor Pregl, the oxidation is completed in from 10 to 20 minutes. Furthermore, there is no danger of an explosion as there is when the Carius method is used. The halogen determination by the micro method can be completed in less than two hours. The average time of a number of runs would be much less. In most cases the micro-analyses are much easier to carry out than the corresponding macro-analyses and repeated checks have shown them to be just as accurate. The technic can easily be acquired by a careful worker. Students with little training in quantitative organic analysis, who have been admitted to the course in organic microanalysis given at the University of Pittsburgh, have not experienced unusual difficulties. Because of the economy of all materials, of space and, of greatest importance, the economy of time, the methods of quantitative organic microanalysis soon spread from the laboratories of biochemistry to the organic-analytical laboratories. The methods are widely used in the European university and industrial laboratories and are rapidly being adopted in this country.



MICRO-KJELDAHL DISTILLATION APPARATUS

To paraphrase a statement of Dr. Dubsky—once one has become familiar with the methods of microanalysis, he will only through necessity go back to the methods of macroanalysis. This fact has been of great value. Chemists familiar with the methods of organic microanalysis, who enter laboratories where the methods are not used, protest forcibly against the use of the standard macro methods of organic analysis. Indications are that the micro methods will soon be the standard methods in common use in university and industrial laboratories, replacing the macro methods entirely. This has already taken place in some instances, notably in Europe, and signs point favorably to the same transformation in American laboratories.

Dr. B. Flaschenträger,[13] writing of Germany, states that Pregl's methods have been adopted in almost all of the chemical laboratories of the uni-

[13] B. Flaschenträger, "Erfahrungen in der organischen Mikroanalyse," *Z. für angewandte Chem.*, **39**, 717 (1926).

versities and great industries. In six years, from 1920–1926, some 3000 carbon and hydrogen determinations, 1000 nitrogen determinations, 200 halogen, sulfur, and methoxyl determinations, and 500 determinations of residues after fusion with sulfuric acid were carried out using the micro methods by or under the direction of this one man working in Munich, Graz, and Leipzig. With these figures the enormous saving in material can be approximately computed. Assuming for the macro methods an average sample of 0.2 g. for each of the 4700 determinations, 940 g. of material would have been required for the analyses. Using the Pregl methods and an average sample of 2 mg., only 9.4 g. of material would have been destroyed in the analytical determinations. In other words, the same number of analytical determinations can now be made with 1 g. of material that formerly necessitated the destruction of 100 g. of substance. Moreover, much time was saved. A microanalyst employed in this work carried out eight carbon and hydrogen determinations and four nitrogen determinations in an eight-hour working day. Figures showing the saving in time would be even more striking than those given for the saving in material. As a result of this experience, Dr. Flaschenträger states: "It should be the aim of all microanalysts to present the micro methods as well as the classical macro methods, so that every chemist who leaves the college has mastered the methods at least once."

The following illustration is given to show that the saving in the material required for analysis may in some cases be a considerable factor. An industrial laboratory in this country is interested in the analysis of an organic substance of unknown constitution which is valued at $5000 per gram. A carbon and hydrogen determination, using a sample weighing 0.2 g. would destroy $1000 worth of the substance, whereas the same determination can be made much quicker by the micro method of analysis using only 0.002 g. of the substance which is worth only $10. Furthermore, at present only about 0.3 g. of the substance is available.

About 1922 the Pregl methods were introduced into the organic-analytical laboratory of the "I. G." Dyestuff Industry, Höchst am Main.[14] Since that time, the many thousands of analyses carried out in that laboratory by the Pregl and other methods of quantitative organic microanalysis have excellently proved their worth by their surety, accuracy, and economy of material and time. On the one hand, they made possible many more investigations than otherwise could have been carried out and many that otherwise would have been impractical. On the other hand, by decreasing the amounts of valuable chemicals used, they led indirectly to greater savings. In that laboratory in six years time, about 36,000 weighings were made on one microchemical balance without any attention being given

[14] A. Meixner and F. Krocker, "Erfahrungen der mikroanalytischen Praxis im Fabriksbetriebe," *Mikrochemie*, **5**, 120 (1927).

to it except the usual cleaning and adjustment required by any balance.

The question has been raised as to whether or not the small amount of sample used in microanalysis was representative of the material. Several investigators[15] have answered this question mathematically and experimentally. For example, a sample of coal weighing 3 mg. is just as likely to be a representative sample of several tons (1,016,064,000 mg. in a long ton) as the much larger samples ordinarily used. The sample must be prepared with the same care in either case. Determinations of moisture, carbon, hydrogen, and ash were made on several samples of coal by both the macro and the micro methods. The agreement was very close. Gesell and Dittmar,[16] of an industrial laboratory in this country, carefully investigated the microchemical methods of analysis from the point of view of industrial economy. The results of the investigation were more than favorable. A main factor of the cost of chemicals is the cost of control. The adoption of microchemical methods of analysis will decrease considerably the cost of control, by decreasing the amounts of material destroyed by analysis as well as the reagents, gas, and equipment used. More important is the decrease in the time consumed by analysis, which facilitates and hastens the progress of merchandise through the plant and enables the plant equipment to be used more times around. Gesell and Dittmar estimate that in large concerns where the laboratory costs run between $20,000 to $100,000 per year, a saving of from fifty to sixty per cent can be made by substituting microanalytical methods for macro analytical methods. They also state that Chemical Microscopy is valuable in many types of control work and is becoming more valuable every day, but where quantitative analyses are necessary it cannot be used.

Today, in our own country, the methods of Quantitative Organic Microanalysis are used in many research institutes and universities, chiefly in biological investigations. Unfortunately, many of our leading institutions have yet to become familiar with and to adopt these methods for routine organic analysis. Rarely are the methods taught to the student in chemistry, except when used in specific investigations. If the methods are to be used extensively in the organic industry, they should be taught to the student in the university. For the same reason that they are valuable to the industry, the methods are perhaps of more value to the university worker who must carry out his research in the so-called "odd moments." Many valuable hours otherwise consumed by analysis will be liberated for research. Many problems with rare and expensive

[15] Strebinger and Radiberger, "Practical Applications of Quantitative Microanalysis, *Oesterr. Chem.-Ztg.*, **22,** 67 (1919); C. Reichard, "Quantitative Mikroanalyse," *Pharm. Zentralb.*, **58,** 483–534 (1917).

[16] Gesell and Dittmar, "Microchemistry as an Industrial Economy," *Ind. Eng. Chem.*, **17,** 808 (1925).

chemicals can be undertaken that might otherwise be prohibited by the budget. For instance, micro-calorimeters have been devised to determine the heats of combustion of rare and expensive organic substances and synthetic work in general can be carried out with much smaller amounts of material. Organic reactions can be studied more completely. Today the investigator can record only in very rare instances that not enough of the material was obtained for analysis. The study of some of these small amounts may throw much light on the mechanism of organic reactions.

From the point of view of the teacher of organic chemistry, the saving of time and material, and the opening of new fields for research are not the only factors to be considered in adopting the methods of quantitative organic microanalysis. Familiarity with and use of these methods influence the work of the student from the beginning of an investigation to the end. It leads to a refining of all of the laboratory procedure, and a better, more exact laboratory technic. The student soon finds out for himself that by developing the technic necessary for working with small amounts of substances, results can be obtained much more quickly and also much more easily than when large amounts are used. The realization that a minute amount of a stray substance formed in an organic reaction can be analyzed and studied, perhaps yielding more important scientific results than a study of the main product increases and makes keener the powers of observation. Then, with only a small amount of an unknown substance to master, the student is spurred on to do his most careful and accurate work. Professor F. Henrich[17] in closing a paper on Quantitative Organic Microanalysis, read before the Bavarian Section of the Society of German Chemists in 1926, states: "It can be recommended that the students in chemistry should be instructed in the micro methods, for to them belongs the future."

[17] F. Henrich, "Methoden der Mikrochemie," *Z. für angewandte Chem.*, **39**, 450 (1926).

Chemical Inhibition Saves Much Money. Inhibition, one of the bogey words of Freudian psychology, has an entirely different and beneficent meaning as applied in industrial chemistry. Minute amounts of chemicals are in some way, as yet imperfectly understood, able to slow down the multifarious process lumped under the head of "spoiling," and these are known as inhibitors. At the Institute of Chemistry of the American Chemical Society, Dr. N. H. Alyea, of Princeton University, explained what is known of these inhibitors and their action.

The most familiar inhibitor is tetra-ethyl lead, which inhibits ordinary gasoline from causing engine knock. A thimbleful of this added to a gallon of gasoline turns the trick. Other inhibitors make tires live longer, keep dyes from fading, and prevent the important new industrial chemical furfural from spoiling. An inhibitor has been found which will prevent butter from becoming rancid, but, unfortunately, it is a poison, so chemists will have to resume the search for one that will do the same work without making the butter dangerous to the consumer's peace of digestion.—*Science Service*

THE VALUE OF THE LECTURE-TABLE DEMONSTRATION IN THE TEACHING OF CHEMISTRY

L. A. WILES, QUINCY, MASSACHUSETTS

The presentation of the increasingly complex body of chemical knowledge and of the numberless useful household and industrial applications of chemistry forms a problem which taxes the resources of the most able teacher. As never before the teacher must organize, classify, collect, reject, and restrict the possible field to what can be encompassed by the average group of pupils in a school year. To accomplish the greatest amount of work with the most economical expenditure of time requires the use of the most scientific methods of teaching. Of several methods available, perhaps the most productive of results in the hands of a skilled teacher is the lecture-table demonstration. While the principle of learning by doing is a generally accepted method in chemistry teaching, as witness our numerous and well-equipped laboratories, yet the most ardent advocate of this method admits that there is a limit to what the pupil can do in the short time allotted. To supplement this method, and to a certain extent to supplant it, the lecture-table demonstration, conducted by the teacher, is assuming a place which makes it worthwhile to investigate its advantages.

Present-day writers are questioning the view that scientific training and scientific information are best gained by practice. The limitations of time make the amount of practical information obtained by a pupil or a class in a school year exceedingly small. The pupil's natural inertia, and the accumulation of apparently unrelated experimental data, blind him to the underlying principles. It is a function of the teacher to correlate, or make the pupil correlate, the data with the theory. It appears that a series of demonstrations conducted by the teacher would advance the pupil, undisturbed by his own manipulations, farther and faster than his own experimental verification. If a pupil's whole class time is devoted to observation and to thinking he will advance more rapidly than when he has to learn unfamiliar manual operations, provided he is stimulated to observe and to think.

There is no "typical" lecture-table demonstration. In its broader aspects it includes the complete, carefully worked out experiment, the exhibition and discussion of charts, pictures, graphs, diagrams, models—in short, as concrete an illustration of the subject under discussion as its nature and the resourcefulness of the teacher will allow. The demonstration usually exemplifies a process rather than a thing, a principle more often than a case. It serves to illuminate a vague generality with the light of fact. The demonstration, used merely as an illustration in a formal lecture, however, has small place in a secondary school.

The three functions of the recitation are to test, to drill, and to teach.

The purpose of the demonstration is to teach. As a teaching instrument, especially in the sciences, it deserves a more general use because of its economy of time and because of the duration of itse ffects. The usual textbook method of recitation has several defects. It does not consider the interest or the viewpoint of the pupil. It is superficial. Results seemingly accomplished are soon lost. The problem or project method requires more time than the curriculum ordinarily allows and is not especially applicable to chemistry due to the large amount of theory. The laboratory method is used considerably in chemistry, but here there is difficulty in correlating the laboratory with the classroom. The time factor is also of considerable importance, if we allow for setting up apparatus and clumsy manipulation. Some laboratory work must be done because colleges and state syllabi require it, but the minimum is sufficient. Much textbook work must be done also because high schools are not equipped to demonstrate such processes as electric furnace reactions and many others. Projects are valuable if they can be done outside of school, but they are too exacting of school time to be used in the classroom. It remains for the wise teacher to make an ever-increasing use of the lecture-table demonstration.

To be successful the demonstration must possess several characteristics. There must be an abundance of concrete material at hand. Pupils may accept a principle on the basis of a single proof, but the more thoroughly it is driven home the longer it will stick. The ability to relate case to principle, and principle to case comes from experience, and the more varied the experiences the easier the correlation. The same preparation should not be used to illustrate more than one idea at a time. It often happens that several theories can be illustrated with one experiment, but it is not wise to confuse the mind of the pupil with all of them at once. It is better to repeat the experiment with each new idea it is intended to exemplify. The preparation for the demonstration should be thorough, and the teacher should be sure by practice that it is going to work. A failure is decidedly harmful to the principle and to the teacher. An element of success is introduced by the use of large-sized apparatus, easily visible to the entire class. The apparatus should not, however, be of such conspicuous appearance as to distract the attention of the pupils from the end sought. The teacher should be well enough rehearsed not to be tied down with notes. Above all the demonstration should not be formal. The teacher must ask questions and the pupil must ask questions. The interested pupil will ask questions but the teacher must make sure that the interest is there. The pupil must be held responsible for both the facts of the demonstration and the principles underlying it. To this end he should be encouraged to take notes on all that happens in class, and should be examined on his understanding of them. Since the demonstration is designed to teach, it should be a serious presentation of facts and a development of their interpretations. Experi-

ments designed to amuse or for pyrotechnical display debase their function. If the pupil is not encouraged to do constructive and logical thinking the demonstration has failed. The success of the illustration requires that the pupil take an active part in its development and in its relation to other facts and to the generalization it exemplifies. He must see that the process is more important than the thing. The demonstration is the means to the end, not the end itself.

Like anything else the lecture-table demonstration may be used with such poor understanding of its possibilities that it is foredoomed to failure. But with it, a resourceful, capable, and earnest teacher can produce results which are lasting, and stimulate an interest that is sincere. No one method, however good, can be used to the exclusion of all others. In considering the advantages of this method, common sense would tell us that it will not do everything. Some things are so simple as to require no demonstration, some so complex as to be beyond the ability of the teacher to demonstrate. The question and answer must be an integral part of the demonstration, else it becomes a mere formal "show" to be taken or left—usually left. The demonstration method has the advantages that it arouses in the pupil real interest in his work, it shows relationships between principles and applications, it helps to keep up the continuity of the subject-matter, it emphasizes the "high-lights" which serve as nuclei of organization and summarization, and with its help the pupil learns faster. On the other hand, it does not call for self-activity on the part of the pupil other than mental and for this reason habits of skill and manual dexterity are not developed. Only the situation, the ability of the teacher, and the needs of the pupils can decide the method to be used. In the last analysis, however, the lecture demonstration will find a prominent place in the classroom technic of every enterprising chemistry teacher.

Bibliography

Twiss, "Science Teaching," Chapters 9–10, 17–23, Macmillan, **1917.**

Rusk, "How to Teach Physics," Chapter 8, Lippincott, **1923.**

Woodhull, "The Teaching of Science," Chapters 7, 10–13, 15, 17, 18, Abingdon Press, **1918.**

Colvin, "An Introduction to High School Teaching," Chapter 12, Macmillan, **1917.**

Foster, "Principles of Teaching in Secondary Education," pp. 39–41, Scribner, **1921.**

Strayer, "A Brief Course in the Teaching Process," Chapters 5, 6, 10, Macmillan, **1911.**

Charters, "Methods of Teaching," Chapters 16, 18–20, 22, Row Peterson & Co., **1912.**

Johnston, *et al.*, "High School Education," Chapters 7–9, Scribner, **1912.**

CHEMISTRY PROJECTS IN HIGH SCHOOL

J. E. MAHANNAH, AUGUSTA HIGH SCHOOL, AUGUSTA, KANSAS

The educational value of projects is well established and their use is not a new thing. Probably most teachers, not only science but others, have used them to good advantage at some time or another. There are a number of good reasons why projects are not used more, some of which are the following: no appropriate time; course of study too crowded; inability to keep all students busy; inability of poor students to do such work; and lack of equipment and reference material.

I generally have a few students in every class who do some project work after school and at odd times. In most cases this work means more than the regular laboratory work as it requires much more initiative and ingenuity on the part of the student to find out how to assemble the apparatus for a given project. But all students cannot spare the time in this manner as the modern high school now demands eight hours or more daily of the average student. The projects as mentioned are done only by the better students who do not necessarily need them from either the interest or credit standpoint. The poor students are the ones that need them for both.

This year we tried a new plan which gave us the appropriate time. The Chemical Essay Contest, conducted by the American Chemical Society, gave us the cue. Until this year, the chemistry students who entered the contest had to write their essays at the same time the other few were doing their projects. This did not seem like a fair deal to either the essay writers or the students who were doing the outside work as both were learning more chemistry at their special task than they would learn in the same time in regular classwork. Of course, both were receiving the necessary encouragement, guidance, and help. In order to give them the needed time and also an opportunity to the rest of the class to really use chemistry once, we decided on a project and essay week. The week chosen was the last full week in February as the essays had to be in by March first. That allowed us to progress as far as possible with the year's work before beginning on the essays and projects.

The essay contest had been announced and explained much earlier. The plan was announced about six weeks before time and since the whole week was to be devoted to essays and projects, each student was required to enter the essay contest or choose a project for the week's work. The projects proved much more popular, in fact, too much so, as would probably be expected. At first, no one wanted to write an essay, but with a little personal effort and explanation, six members chose the essays, leaving eighteen for the projects.

The essayists were given a few days to select their subjects. The search for material then started. When the appointed time arrived, the outlines

were well along and most of the material at hand. A special room with tables was provided so their material could be left without disturbance. Full coöperation was given by the English department, both in correcting the essays and in giving extra credit to the contestants who were enrolled in composition courses. The other members of the class were allowed to choose their projects, so long as it was appropriate for the allotted time and our equipment. As suggestions, the following list was posted and it happened that each student chose his from the list, although some of the more ambitious wanted to do such things as prepare artificial diamonds. The list included:

1. Photography—taking pictures, developing negatives, and making prints.
2. Making lantern slides.
3. Making enlargements.
4. Finding alcoholic content of drugs.
5. Preparation of charcoal, wood alcohol, and acetic acid by destructive distillation of wood.
6. Preparation of inks.
7. Preparation of esters—banana oil, ethyl acetate, etc.
8. Preparation of silver nitrate from silver alloys.
9. Preparation of potassium carbonate from wood ashes.
10. Identification of rocks and minerals.
11. Etching glass and metals.
12. Recovery of gold and silver from old jewelry, pens, etc.
13. Silvering mirrors.
14. Electroplating.
15. Chemical cleaning of silverware.
16. Water testing—distilled, cistern, well, etc.
17. Measuring hardness of water.
18. Preparation of calcium chloride from marble.
19. Analysis of different brands of vinegar.
20. Analysis of different brands of ammonia water.
21. Analysis of petroleum—per cent and Baumé gravity of gasoline, kerosene, gas oil, and fuel oil.
22. Analysis of alloys.
23. Analysis of milk.
24. Analysis of coal.
25. Finding per cent of cotton, wool, and silk in cloth.

The projects had to be chosen a week or more before the work was to start so that any needed material or chemicals not in stock could be procured in time. The students were required to have a good idea of the methods they were going to use before time to start. Seventeen projects from the above list were carried out by the class, some members doing two or three of the shorter ones. The ones not chosen were numbers 6, 14, 15, 16, 19, 24, and 25. Most of the projects selected were common chemical applications, but a few deserve special mention.

Probably the most difficult project was the destructive distillation of

wood. On account of the amount of wood required for a sample of methyl alcohol, an iron still was made from a three-inch gas pipe about 15 inches long, fitted with two screw caps, one of which was tapped for a quarter-inch delivery tube. This was easily charged and heated so the dry distillation did not take very long. The separation and partial purification of the alcohol and acetic acid were more tedious procedures. Waste oak blocks from the manual training shop were used for charging stock. This project required more time than any other one.

One of the most successful ones from a teacher's standpoint was the preparation of potassium compounds from wood ashes. With practically no suggestions or help except the few general statements in the text, one of the country boys prepared and purified potassium carbonate. From it he made samples of the hydroxide, chloride, nitrate, and sulfate, and used some of the nitrate in preparing some gunpowder.

Practically all of the glass etching was done with liquid hydrofluoric acid rather than the gas. Some rather artistic designs were skilfully made on watch crystals, water sets, mirrors, and auto windows. Most of the metal etching consisted of putting designs on book ends made of sheet metal, mainly copper and brass.

In preparing calcium chloride from marble, the student noticed that his solution was colored and wanted to know the cause. After being informed that the color was due to certain impurities and what ones were probably causing it, he tested for them and found them. From a few more suggestions, he cleared up his solution, much to his delight.

One of the boys brought a sample of crude oil from a new oil well near his home and ran an analysis on it. While one of the poorest students, he worked out the per cent of gasoline, kerosene, gas oil, and fuel oil with the Baumé gravity of each in a very creditable manner.

Wherever possible, exhibits of the projects were prepared by using the raw and finished products with a brief description of the process and the student's name. These certainly will do more toward advertising the true nature and value of chemistry to the students and patrons than the over-emphasized fumes and gases. The students' own work will also appeal more to others than would that of industries or experienced chemists.

One of the essay writers suggested that they be given a chance to learn of the work that was done so each student gave a report of the work that he did. This was worthwhile to the others that were in the laboratory as they did not have much chance to investigate others while they were working. Some of the essay writers and others kept working on the projects after their week's assignment was completed.

The apparatus required for any project was left set up until the project was completed. A school having more than one chemistry class or one that uses the room regularly for other classes would be handicapped some in

this respect although very few required anything more complicated than that of ordinary experiments. I can also add that there is seldom a time when we are without one or more special "set-ups," which are left from one to three weeks. The extra equipment and chemicals needed were bought by the chemistry department from a fund which is raised by charging each student a fee of one dollar for the year. This fund was used for the direct benefit of the class in buying standard tests, periodicals, and other supplies that will be used during the year.

Project week was a revelation to both students and teacher and certainly not a vacation for either. It represented the greatest amount of conscientious work on chemistry by each student that I had ever witnessed. Most of them spent time outside of school and several study periods outside of the regular class hour. It was a question of keeping them out rather than getting them in. I had to remind some that they had other subjects—a procedure which is a little out of the ordinary, especially for a chemistry teacher. The work progressed well with some unusually good and some negative results, as far as the primary purpose was concerned. The same would be true, even with experienced chemists. Probably the greatest feat was going through the week without an explosion or even a single burn.

Most of the objections to such work vanished. The time was well spent by every student without exception. The poor students received the greatest individual good as the whole thing was new to them and they were actually enjoying the use of their hard, dry subject. All showed more initiative than was expected. This is also a change for a teacher as it gets him out of the beaten path for a few days and incidentally gives him a new perspective of his field. He probably learns considerably more than his students.

This is no attempt to give the idea that everything worked out perfectly. There were failures and enough to show the class that results are not always according to theory. The latter represents a lesson which must be learned sooner or later by all. However, the results as a whole were satisfactory, much more so than were ever expected. Many defects were noticed but some of them can be avoided next time. Personally, I think the projects should come at least a month later but that is impossible if they are to be run simultaneously with the essays.

Next year I hope to get a variety of foreign raw products for demonstration work and projects by exchanging our raw product, crude oil or petroleum, for them. I intend to write out the laboratory method, as used by the refiners, for petroleum analysis and have it mimeographed. Then I will be ready to express a gallon of crude oil, with directions for analysis, in exchange for a peck of sugar beets or for samples of important ores and minerals or for various other things that different ones want to ex-

change for crude oil. While general methods are given in the texts, a few detailed laboratory instructions may be a great time saver, something of much importance when about twenty different projects are to be carried on at the same time by beginners.

As is well known, industries and even home processes are depending more and more on chemical science. Men and women without any training in chemistry are required to do certain chemical procedures, such as soften water, test the hardness, alkalinity, and causticity of treated and untreated waters, use carbon dioxide recorders, run analysis on flue gases, test the acidity of cream, and do various other things of like nature. High-school chemistry is going to be a great help in doing these things. Since that is all that many of the class will get, they ought to get a little experience in their class work. The project gives the opportunity.

With all the advantages as given, the projects cannot take the place of regular class and laboratory work but they certainly make an important adjunct.

Coal Mine Like Explosives Magazine. The hazards of coal mining are vividly demonstrated by the Mather mine disaster. Coal is an explosive, especially in the form of dust, and in coal mines, as in powder plants, every precaution is necessary in order to prevent explosions and fire.

Government and state regulations and advice have placed in the hands of mine operators the most effective methods of guarding against disasters. All sparks and other sources of ignition of the coal or the gas that it generates must be prevented. Electric cap lamps are recommended and these were used in the Mather mine. Explosives that do not send out a flame in detonating and machinery that does not spark are necessary. Coal dust must be prevented and fought continually. Water is played over the cutting instruments, the coal is wet down as it is shoveled and carried out of the mine. Plenteous drafts of fresh air must be circulated to all parts of the mine, especially where the coal is being cut.

Rock dusting is a recently developed method of making the coal dust non-explosive. Finely pulverized inert material is spread in the mine and mixed with the coal dust so as to dilute it If more than 65 per cent of the mine dust is incombustible, the mixture cannot take fire or explode. Every portion of the mine must be thoroughly and constantly rock-dusted for complete safety. Just as one match in a powder magazine brings disaster, so one explosive area in a mine may cause the loss of miners and mine.

Mather mine is listed as partially rock dusted and experts believe that the explosion must have occurred in the portion that was unprotected. About a quarter of the coal tonnage comes from mines that are partially or entirely rock-dusted.

In the rescue crew of the U. S. Bureau of Mines at Pittsburgh which rushed to the scene are veterans of many mine disasters. George McCaa of the crew is credited with being the best rescue man in the world. J. J. Forbes, in charge, comes a close second, while the six other experts are the men who teach mine safety methods to the thousands engaged in the mining industry. Crack rescue teams from other mines also answered the emergency call. The U. S. Bureau of Mines trains 25,000 to 40,000 miners in first aid and rescue methods each year and in some mines in Illinois, Kentucky, and West Virginia every miner is trained.—*Science Service*

CHARLES FREDERICK MABERY, A PIONEER*

W. R. VEAZEY, CASE SCHOOL OF APPLIED SCIENCE, CLEVELAND, OHIO

Franklin K. Lane has written the following lines about the American Pioneer—"He is the adventurous spirit of our restless race. He landed at Plymouth Rock and with his dull-eyed oxen has made the long, long journey across our Continent. . . . His way has been hard, slow, momentous . . . . and he never turned back. Here he stands at last beside this western sea, the incarnate soul of his insatiable race, ... the American Pioneer."

Charles Frederick Mabery was a native of Maine, of Scotch-Irish stock, a true pioneer in the field of American petroleum. He was known and respected the world over and his work is cited and discussed in all recent books which deal with the composition of natural mineral oils. Dr. Mabery was born at New Gloucester, Maine, on January 13, 1850. He attended the schools of Gorham and Kents Hill Seminary and after graduation taught in the schools of Maine for five years. In 1873 he entered Harvard and in 1876 graduated from the Lawrence Scientific School with the degree of Doctor of Science. He remained at Harvard for eight years as an assistant in chemistry and for ten years he was director of the Harvard summer school in chemistry for teachers.

In 1883 Dr. Mabery accepted the professorship in chemistry at Case School of Applied Science in Cleveland, Ohio. At that time the chemical laboratory was in a brick barn near the old Case homestead on Rockwell Street, not far from the site of the present Cleveland Public Auditorium. It was in this laboratory that Dr. Mabery's research work really began. In 1885 the school was moved to a new building on Euclid Avenue opposite Wade Park and the chemical laboratory occupied a portion of the third floor. Unfortunately, this building was burned in October, 1886, and the chemistry department was then quartered in a frame house, which is still standing at the rear of the present campus and is used as a dwelling by one of the janitors.

In 1892 the present chemical laboratory which was designed by Dr. Mabery was completed. These first ten years of service at Case were strenuous ones for a young professor—a new school, new courses to be developed, a small teaching staff, a large burden of teaching, many executive duties, three different laboratories to plan and equip. Many a man would have considered himself fully occupied but the records show that during this very period Dr. Mabery and his assistants accomplished a large amount of valuable research. Fourteen papers were published, the titles of which indicate somewhat the breadth of vision and the scope of interest in the general field of chemistry which Dr. Mabery had. Usually

* Paper read before the Section (now Division) of Petroleum Chemistry of the A. C. S. at Detroit, Mich., September 8, 1927.

such a list of titles and authors is quite uninteresting but this one is very attractive and withal quite surprising:

1. "Brom-tetra-chlor-propionic Acid," by C. F. Mabery.
2. "Composition of Certain Petroleum Oils and Residues," by C. F. Mabery.
3. "Sulfur Compounds in Ohio Petroleum," by C. F. Mabery and A. W. Smith.
4. "The Electric Furnace and the Reduction of the Oxides of Silicon, Aluminum, Boron and Other Metals, by Carbon," by Eugene Cowles, Alfred Cowles, and C. F. Mabery.
5. "Substituted Acrylic and Propionic Acids," by C. F. Mabery.
6. "Composition of Products from the Cowles Electric Furnace," by C. F. Mabery.
7. "Lithium in Certain Cleveland Well Waters," by C. F. Mabery.
8. "Bromine and Lithium Content of Northern Ohio Salt Brines," by C. F. Mabery and Herbert H. Dow.
9. "Influence of Aluminum on Cast Iron," by W. J. Keep, C. F. Mabery, and L. D. Vorce.
10. "Action of Aromatic Amines on Unsaturated Acids," by C. F. Mabery.
11. "Substituted Acrylic and Propionic Acids," by C. F. Mabery and A. W. Smith.
12. "Action of Aromatic Amines on Brom-propionic Acid and the Substituted Acrylic Acids," by C. F. Mabery and A. H. Krause.
13. "Sulfur in Petroleum and Petroleum Residue," by C. F. Mabery and A. W. Smith.
14. "A New Method of Preparation of Anhydrous Aluminum Chloride," by C. F. Mabery.

In his annual report to the President for the year 1893, Dr. Mabery said: "The paper on salt brines led to the perfection by Mr. Dow of a process now in operation for the extraction of bromine from brines that promises to replace the older methods." With reference to the papers on sulfur in petroleum he said, "Although many methods have been proposed and protected by patents for the removal of sulfur from Ohio petroleums, our results gave the first information concerning the forms of sulfur compounds in these oils." In connection with the electric furnace paper, he said, "Since 1884 investigations have been constantly in progress in this laboratory on the metallurgy and uses of metallic aluminum and its alloys and they have contributed to the great reduction in price of the metal and to its more general use in the arts." It is truly remarkable that during these first ten years at Case, Dr. Mabery found time to have an important part in the beginning of the development of three large American industries, bromine, aluminum, and petroleum.

After the completion of his new laboratory in 1892, Dr. Mabery, though still retaining an interest in a variety of fields, turned his attention largely to the determination of the exact composition of petroleum. The guiding principle in all his petroleum studies is splendidly set forth in a paragraph from his address at the dedication of the new laboratory—"The application of chemical principles seldom precedes a good understanding of the principles themselves. Operations may indeed be carried on in a haphazard

fashion according to empirical rules but the results are apt to be unsatisfactory. We should therefore expect to see the development of technological chemistry follow the general advancement of scientific knowledge. No process involving chemical changes can be conducted intelligently and economically unless it is carefully controlled by a complete knowledge of the materials employed, the valuable products obtained and all the waste products as well."

Dr. Mabery's researches were always guided by the spirit of this principle. At the time that he determined to separate and identify the individual compounds contained in that most complex mixture which we call petroleum, probably no more difficult line of work could have been undertaken. The methods of work and even the apparatus had largely to be developed for this particular purpose, and the task appears many-fold greater when we realize that nearly all the actual laboratory work had to be done in spare time, outside the regular school hours, by one man in one small laboratory. Early in the morning and late at night Dr. Mabery worked practically alone for more than forty years in his endeavors to establish the scientific principles which would lead to intelligent and economical technology in the petroleum field. It would be extremely difficult to evaluate the detail of his work in connection with modern petroleum refining practice but it is easy to see the stimulus which his publications have given to the intensive scientific study of petroleums which is now in progress.

Dr. Mabery was a rugged character. He possessed a determination and persistence which overcame repeated failures and multiplied discouragements. He had a splendid physique and a seemingly unlimited supply of energy, but his continuous application to detailed work undermined his health and this made it necessary for him to retire from active teaching in 1911. But it was characteristic of Dr. Mabery that he did not retire from work. Year after year he spent eight or nine months from early morning to late evening at his favorite research. Each summer Dr. and Mrs. Mabery returned to his native state for a vacation but his thoughts were continually in his Cleveland laboratory. Aside from his chemical work Dr. Mabery was a lover of art and he had many connections with the art activities of Cleveland. He took an active part in the development of the Cleveland School of Art and the Cleveland Art Museum.

In 1923 Dr. and Mrs. Mabery availed themselves of an opportunity to in a measure satiate a lifelong appetite for art and music by making a tour around the world.

Not until the winter of 1927 did he give up his annual practice of a season of hard work in the laboratory. During the fall and early winter of 1926 Dr. Mabery devoted his entire time to attendance upon Mrs. Mabery, whose health was rapidly failing. After Mrs. Mabery's death,

Dr. Mabery decided to discontinue his scientific work and devote himself to writing and lecturing about his travels in various parts of the world but death stayed his hand on June 26, 1927, at Portland, Maine.

Dr. Mabery was truly and rightly distinguished all over the world as a pioneer in the difficult field of petroleum research and his life and work are a beacon light to all who are now following and shall later profit by the trails to new fields of opportunity which he has blazed.

Gangrene Cause Successfully Treated by X-Rays. The conquest of troublesome and persistent diseases of the neuro-circulatory system by x-rays was described to the American Medical Association by Dr. Herman B. Philips of New York recently.

A stimulating and relatively light dose of Roentgen rays is directed, not at the portion of the body affected, but at the portion of the spine through which run the nerves that control the portion of the body diseased.

Cases of the circulatory disease, known as thrombo-angitiis obliterans, in which the legs and hands often lose their circulation and gangrene sets in, were successfully treated by the method devised by Dr. Philips. Senile arteritis, another serious circulatory disease of advanced age, has also proved amenable to the method. Gangrene, with consequent amputations, is the result of some of these diseases which are relieved by the x-ray. Many patients incapacitated and helpless have been rendered comfortable and restored to working condition, Dr. Philips reported.

Angina pectoris, Raynaud's disease, and certain skin disorders have also been treated in this way with enthusiastic reports. As these are disorders that are none too responsive to therapeutic measures, the physicians look forward to new advances in their control.

Dr. Philips declared this method of Roentgen radiation to offer "an incomparable therapeutic agent, simple, safe, available to all and successful in the great majority of cases."—*Science Service*

Reading Rotogravure Sections Causes Unusual Skin Disease. Disease lurks within the pages of the rotogravure sections of the Sunday newspaper and those rare individuals who are susceptible to this new skin eruption, recently described to the American Medical Association by Dr. Edward A. Oliver of Chicago, must forego the pleasure of reading the brown picture sheets on doctor's orders.

A patient came to Dr. Oliver suffering from a dermatitis that was not cured by ordinary remedies. Realizing that it was probably due to some irritating substance, he was told not to use hair lotions, dyed clothes, or to come into contact with other known skin irritants. The eruptions continued, but Dr. Oliver noticed that they were worse on Monday or Tuesday, indicating that the infection occurred on Sunday. The only difference in the patient's life on Sunday was the fact that he read the Sunday papers and since the Sunday papers differed from the daily editions only by the inclusion of the comic and rotogravure sections, these portions of the newspaper were suspected. The comics were exonerated, but the roto pictures were found guilty. When the patient shunned the familiar brown ink sections, he recovered and remained well.

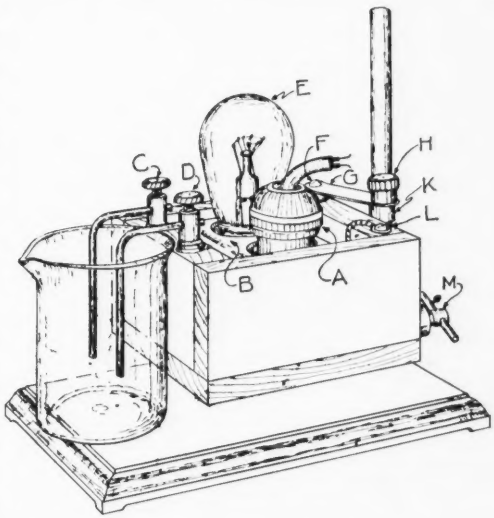
Fourteen other cases were discovered and cured subsequently. Dr. Oliver traced the cause of the irritation to a dye used in the brown rotogravure ink, known as a diazo color, para red. This type of skin disease, that inflames the face, eyelids, and sometimes the neck, is not believed to be very widespread and seems to occur only in those who have an idiosyncrasy to the special sort of ink used in rotogravure printing. Ordinary ink has been found to be harmless.—*Science Service*

A CONDUCTIVITY APPARATUS

JESSE E. DAY AND FORD C. DAVIS, THE OHIO STATE UNIVERSITY, COLUMBUS, OHIO

Several models of conductivity apparatus for first-course chemistry students have been described in either laboratory manuals or the literature. Some of these are constructed so that they may be used at the desk of any student and some of them are for fixed laboratory locations. All of them possess the merit of inexpensiveness.

Three years ago the authors built the apparatus shown in the drawing. A General Electric No. 36537 porcelain 30 ampere, double pole covered main-line cut-out is the receptacle, *B*, for the 10-watt, S 14 clear lamp, *E*, and the Bryant No. 699 split attachment plug, *A*. One pole of the attachment receptacle is wired to the open binding post, *D*, and the other to the round-head wood screw, *L*; one pole of the lamp receptacle is connected to the post, *C*, and the other to the screw, *F*. The contact strip, *G*, is a radio bus strip and the button, *H*, the insulated nut of a radio binding post, the latter being attached to the former by means of a machine screw and the whole (excepting the contact points) covered with liquid Bakelite. The enclosing box is of soft wood treated with oil stain and the attaching clamp, *M*, is from a funnel support. For safety from a "short" a piece of rubber tubing, *K*, is placed on the rod of the ring stand opposite the contact bar. The electrodes are of #6 soft copper wire.



The apparatus is more expensive than any referred to in the introduction but has several offsetting points in its favor, particularly when needed in fairly large numbers by large classes. (1) The feed wires are enclosed which eliminates the "blowing" of fuses. (2) The electrodes are well outside the apparatus which lessens the likelihood of solution "shorts" resulting from spillage. (3) Current flows only when the key is closed. (4) The apparatus can be attached to the "plug-in" box on the student's

desk. (5) Being portable, each student may thus be held responsible for the condition of the apparatus. (6) The apparatus may be raised or lowered (to the extent of the height of the support rod) to accommodate the conductivity vessel. (7) When the lamp and attachment cord (with the upper part of the split plug) are removed and the electrodes folded up and pushed back, the apparatus may without risk of damage be stored in a small space.

Chemists Seek Way to Unmix Oil and Water. The old adage that oil and water can't be mixed makes the oil producer smile wryly when he hears it. For like many another proverb it is very far from the truth, and in this instance it is a most expensive joke on the oil man, according to Dr. Gustav Egloff of Chicago, who spoke before the Institute of Chemistry of the Amerian Chemical Society, held recently at Evanston, Ill.

Oil and water do not mix as a chemical compound, it is true, but they often come out of oil wells together in that very intimate physical mixture known as an emulsion, wherein very fine droplets of one are suspended in the other and won't come out without the most troublesome and expensive of treatment. Thus it has resulted that nature every years burdens the oil industry with 200,000,000 barrels of intimately mixed oil and water as emulsified crude oil. Such oil does not separate its water even after years of storage. To refine emulsified crude oil into dry oil and water is both difficult and expensive.

"There are at present over 100,000,000 barrels of emulsified crude oil in storage tanks and in sump-holes in the ground, and the refiner is at his wits' end as to how to separate the oil from the water," Dr. Egloff stated. "Thus over $100,000,000 is tied up in stored emulsified oil for whose utilization no really economical method has been evolved which is applicable to all situations.

"Not alone do we have nature producing highly stable emulsified oils, but they are also produced in the refining process, particularly in the manufacturing of lubricating oils. As a matter of fact extremely thorough refining is necessary to produce lubricating oils which will not emulsify under service conditions in motors and turbines."—*Science Service*

Beri-Beri Results from Prohibition. In the United States people are getting wood alcohol poisoning and shotgun wounds from prohibition. In the Pacific Island of Nauru they are getting beri-beri, Dr. G. W. Bray reported recently in London to the Royal Society of Tropical Medicine.

This severe nutritional disease, resulting from a lack of vitamins in the diet, appeared in Nauru shortly after that country became a mandate of Australia and, curiously enough, is most prevalent during the dry season. Supply of alcohol to native peoples of mandated territory is not allowed. The natives of Nauru make their fermented beverage from the toddy palm which contains large amounts of yeast. Apparently the absence of this drink from their diet, with the accompanying absence of the yeast that supplied vitamins, resulted in the appearance of beri-beri.

The people of the island never touch rice, which has usually been the main food of populations suffering from beri-beri. The disease occurs only among breast-fed infants, thereby upsetting another dietary theory. Feeding these infants concentrated toddy cured them of the disease.

Consumption of toddy has not entirely stopped since the mandate, although it is much reduced. During the wet season the toddy palm yields much more of its fermentable sap, which accounts for the higher number of cases during the dry season.—*Science Service*

MODERN CHEMISTRY IN MEDICINE

SIDNEY S. NEGUS, THE MEDICAL COLLEGE OF VIRGINIA, RICHMOND

Due in large measure to Doctor Herty's influence and interest in the coördination of biochemistry with other medical branches in the diagnosis of disease, a new plan is being tried out at the three hospitals of the Medical College of Virginia. Doctor William B. Porter, professor of medicine, is a strong advocate of the importance of chemistry in diagnostic work. Under his direction the new clinical chemistry laboratory has been built and has started functioning. Under the new plan a well-trained Ph.D. biochemist has become clinical chemist for the hospitals. The clinical pathologist has working with him, therefore, a trained biochemist who is able to interpret results.

The research laboratory of the clinical chemist is in one of the hospitals and close to him are the routine laboratories over which he has supervision. Trained technicians take over the routine work and the clinical chemist spends his time in introducing new and better analytical methods, doing the more difficult analyses, and undertaking research in coöperation with men in the other medical branches. Papers resulting are to be published with the medical man, pathologist, or bacteriologist, and the chemist as co-authors. The clinical chemist becomes the referee on all chemical analyses done in the routine laboratories which do not seem to accord with other diagnostic data. The chemists have access to all medical histories of patients and may suggest to the surgeons and physicians the analyses which would be of importance and those which would have no bearing on the particular case.

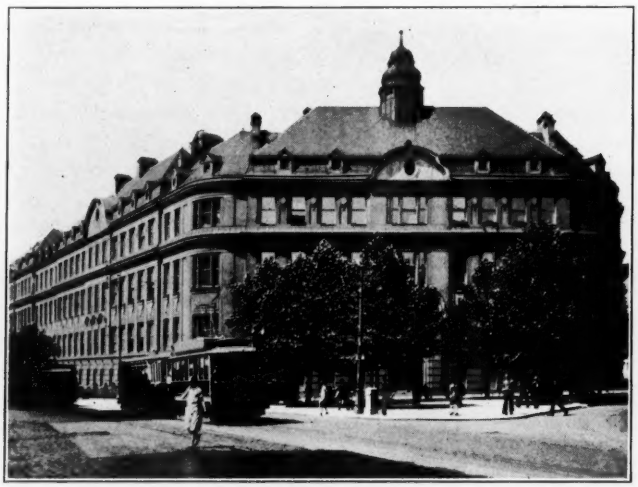
Technicians are to be trained in their practical chemical work in the routine laboratories under a master technician. Students desiring to do original work on some chemico-medical problem are to work in the clinical chemist's private laboratory under his direction. Instructors in the department of chemistry who have courses in biochemistry for pharmacy, dental, and medical students have free access to the clinical chemistry laboratory for materials of practical interest, like pathological urines, bloods, spinal fluids, and gastric contents. Students of biochemistry, especially those in the medical school, are to be allowed the privilege of seeing patients in the wards on whom they may be running tests in their laboratory work.

Besides serving the three hospitals of the Medical College the plan is being worked out so that it will be of value to physicians and surgeons in the city and state. The plan is an endeavor to link up more closely chemistry with medicine in diagnostic work, making it more coördinate in importance with pathology, bacteriology, and the other medical branches.

CHEMICAL EDUCATION AT THE UNIVERSITY OF VIENNA*

JOHN S. REESE, IV, WILMINGTON, DELAWARE

Cities, like people, have true personalities and Vienna certainly possesses one of distinct charm. It is perhaps for such a reputation that Vienna is unappreciated by many Americans as a center of modern education. Celebrated for its school of medicine, one finds that other fields of science, specifically chemistry, have by no means been neglected. Indeed one has only to pass down *Waehringerstrasse*, just a step from the famous *Ring-*

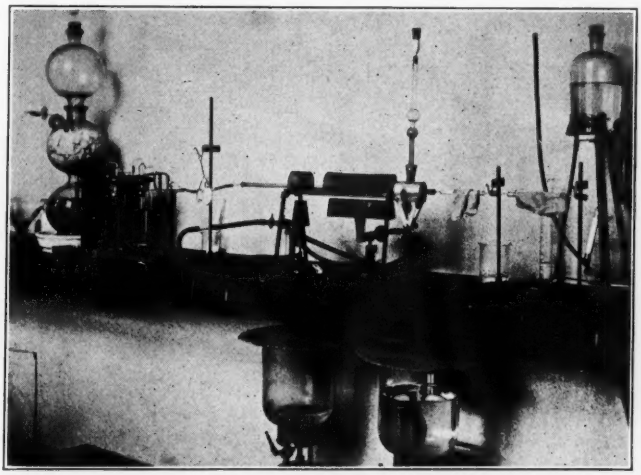


THE FIRST AND SECOND CHEMICAL INSTITUTES

strasse, to be convinced of this fact. Here are located the chemical laboratories of the University of Vienna, in a truly imposing group of buildings. Although a good part is devoted to physics, one finds here four distinct chemical laboratories. Of these the two largest are "The First Chemical Institute" and "The Second Chemical Institute," each possessing its own equipment and faculty. They are directed by Professors Wegscheider and Spaeth, respectively, and a student may receive his entire chemical training in either one. In addition there are two smaller laboratories in which only research is carried on. The first of these, sharing building equipment with "The Second Institute," is headed by Professor Franke, while the other, "The Institute for Chemical Technology," is under the leadership of Professor Pollak and is associated with the "The First Institute."

* Paper written while Dr. Reese was studying at the University at Vienna, 1927–28.

The buildings which house these laboratories are in every respect modern, with all conveniences such as excellent lighting and first-class ventilation. Likewise the lecture halls possess splendid equipment and exceptional acoustics. Indeed, the laboratories have been but recently equipped, though their construction was begun in the year preceding the World War. At that time Vienna was the center of the old Austrian-Hungarian Empire and its educational facilities were designed to meet the needs of some fifty millions, yet today these same facilities are crowded by a people amounting to only six and a half millions. An education in Austria costs nothing and already this little country is over-educated and, to be specific, has far more trained chemists than can possibly find proper employment. As a matter



MICRO-ANALYTICAL APPARATUS IN THE LABORATORY OF CHEMICAL TECHNOLOGY

of fact, the over-crowded laboratories have much available though unequipped space. Lack of funds is the cause of this, while the over-crowding is done to meet current expenses. In the Chemical Technology laboratory there is a limited capacity of thirteen students, yet it is crowded with nineteen prospective Doctors of Philosophy and annoyed with a waiting list of nearly sixty.

This laboratory, "The Institute for Chemical Technology," was organized as a separate unit some years ago under the capable leadership of its present director, Professor Pollak. Its purpose was to provide a distinct school for the training of young men as "Koloristen" in dyeing processes, in which field of chemical education Vienna has traditionally held a place

second only to Lorraine. Its laboratory, though small, contains ample equipment for a limited number of students and possesses in addition a well-developed division for micro-analysis and in the basement a well-equipped semi-works laboratory. The latter consist of a "Färberei" and a newly equipped room for the preparation of dye intermediates. The work done in the laboratory proper is intended entirely for doctor's dissertations

COLOR ROOM IN THE LABORATORY OF CHEMICAL TECHNOLOGY

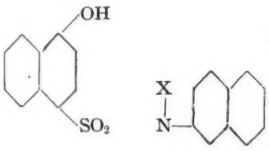
and is necessarily purely scientific, while such practical applications as are possible are tried out in the basement. In regard to such equipment as glassware, a student may borrow from the limited laboratory supply. Chemicals may likewise be obtained in the building though the limited supply often causes much inconvenience. Nevertheless, the universal low cost contrasts strikingly with conditions in America. But perhaps more consideration of the students themselves would be of interest.

As a rule one finds quite a diversified group of people; for example, in the laboratory above described, there are among others a Swede, who during the war served as an officer in one of the famous Austrian regiments, two Hungarians, a Prussian, a Pole, a Mexican, a Russian, and the writer, an American. Among the few remaining Viennese, there are several young women. The proportion of women to men in these laboratories is much greater than in America though few of them actually follow chemistry as a profession. These particular students have all passed a preliminary examination with their professor requisite to starting work on their doctor's dissertation. When eventually such research has been accepted, the

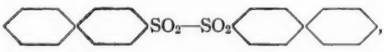
student goes to his books and when sufficiently prepared presents himself to the faculty for a final examination. As a prerequisite to this examination he must, however, have sustained an examination in pure philosophy and likewise in a minor subject such as physics, biology, etc. In all this work a student may attend lectures when and where he pleases. However, he usually favors those professors to whom he has paid a fee and under whom he must take his examinations. No study is at any time compulsory and a student prepares himself entirely according to his own inclinations.

Nevertheless, before commencing his doctor's dissertation and the work outlined above, a student must ordinarily have been in the University for about three years. Of these the first two are devoted to inorganic and physical chemistry, the only required work, however, being two semesters, or a year each of qualitative and quantitative analysis. Examinations follow the completion of each division of analytical work and a final examination on the inorganic field comes usually at the end of the second year's study. The student then must accomplish what is usually a year of laboratory work in organic chemistry and terminated by an examination. Thereupon the student may present himself when prepared for a final comprehensive examination covering inorganic, organic, and physical chemistry and physics. The same independent method of study prevails during this period as later, and this freedom obviously causes some variation in length of time required to become a Doctor of Philosophy. However, by conceding three semesters for an acceptable thesis, the average length of training amounts to a total of between four and five years. It would appear from this outline that a chemist's higher education is indeed narrow, but for admission to the University a young man must have satisfactory records from either a *Gymnasium* or a *Realgymnasium* where he has mastered the humanities as well as modern languages, history, and probably higher mathematics. A young man is, on the average, eighteen years of age when leaving the *Gymnasium*. It is of interest that there are no private schools to mention, and that all children, rich and poor alike, receive the same education in the same schoolrooms. Having now given some idea of the equipment and students, some consideration must be taken of the more important research efforts made in these laboratories.

As mentioned above, much of the work in the "Laboratory for Chemical Technology" has to do with dyestuffs. Many of the recent investigations have been concerned with phenolsulfonylchlorides in the preparation of vat, azo, and ice dyes, and also with aromatic sulfur containing compounds in which the sulfur may be di-, quadri-, or hexavalent. The following compound is typical of many intermediates which have been prepared and which give not only very fast but also very cheap dyes:



Dithioindigoes, alizarin and its derivatives are also being investigated. Of a more theoretical nature has been an attempt to prove the existence of sulfur radicals such as . Their results, however, were negative for only the doubled compound,



was obtained in this case. Of late, work has been done on solution mediums of cellulose, for example, sulfocellulose. In the other laboratories there is the work of Prof. Spaeth on alkaloids, whose recent solution of the constitution of cotoin, based on previous work of Pollak and Karrer, is worthy of note. Prof. Klemenc should be mentioned for his work on the equilibrium of nitric acid and Prof. Pollak, though at present engaged in no particular research, is making important contributions in organic chemistry to Abderhalden's new handbook for pharmacists. The work of Prof. Feigl is perhaps the most original. His new organic-inorganic complex compounds, in addition to a purely theoretical interest, provide an excellent series of new qualitative tests.

In closing, it might be remarked that the study of chemistry and the chemists themselves are much the same the world over, despite a great difference in method and superficial things. There is, however, one important difference in the European system which should be noticed by Americans. One finds that the responsibility of accomplishment rests completely with the student and not with the teacher. It need scarcely be remarked that the contrasting condition existing in America is already recognized and one hopes that a complete change will eventually come.

Ice Cakes Become Standardized. Now the ice cake that meltingly does its part in combating summer heat is to be standardized. The U. S. Bureau of Standards has issued standard weights and maximum sizes for the chunks of frozen water that the ice man puts into the refrigerator daily. Cakes of 25, 50, 75, 100, and 150 pounds are declared standard and for these weights maximum dimensions are specified. The smallest weight, 25 pounds, must measure less than 12 by 12 by 8 inches, while the 150 pound cake must not exceed 12 by 24 by 24 inches. Manufacturers will shape the ice compartments of refrigerators so that the standard cakes will slide into them easily.—*Science Service*

THE COMBINING RATIO OF COPPER AND SULFUR. AN EXPERIMENT FOR HIGH SCHOOLS

CHARLES H. STONE, ENGLISH HIGH SCHOOL, BOSTON, MASS.

The laboratory work for beginners in chemistry should include a few quantitative experiments; three or four of these may be given during the year. Such experiments should be simple in method and easy of performance, for the average pupil has not the skill to do exact work and has not acquired an appreciation of the need of care in doing such determinations. For a number of years the writer has used with satisfaction the following method for determining the ratio in which sulfur and copper combine. The original idea was found in a laboratory manual by Bradbury.[1] The balances used are of the ordinary horn-pan kind and the weights are the ordinary box weights ranging from 10 g. to 0.01 g. The experiment can be completed in about 45 minutes.

Proceed as follows: Wind about six or seven feet of No. 30 bare copper wire around a test tube to form a small coil. Fasten the coil loosely together. Weigh to 0.01 g. a no. 00 porcelain crucible without cover. Put the wire coil into the crucible and weigh crucible and wire to 0.01 g. Find weight of wire by difference. Remove crucible from balance pan, using forceps, and put into the crucible about one or two grams of sulfur flowers. This should not be done while the crucible is in the balance pan since some sulfur may fall onto the pan which would spoil later weighings. It is not necessary to weigh the sulfur since any excess of it will burn and pass off as sulfur dioxide later in the experiment.

The crucible is now placed on a triangle on the large ring of the ring-stand, the cover placed on it, and heat applied. Heat gently at first, but gradually increase the heat until the full power of the burner is reached. Blue flames will escape due to the burning of the excess sulfur. Keep at a red heat for five minutes after blue flames cease. Let the crucible cool. When cold, remove cover and weigh crucible and contents to 0.01 g. By difference find weight of contents, the crucible remaining constant in weight. From the weights of the copper wire and the product formed, compute the per cent of copper. Reduced copper could doubtless be used but we have not tried it.

The following results were obtained in the author's classes during the past winter. Highest per cent of copper 80.9; lowest per cent of copper 78.2; average for 53 boys, 79.7+. The theoretical per cent based upon the atomic weights, Cu = 63.57 and S = 32.06, is 79.86.

Several questions may arise in the mind of the teacher or the student in regard to this experiment. Is not cupric sulfide formed? Is it not possible that some oxidation may occur? Is it not possible that there may be a small core of the wire which is not completely sulfurized?

The best information available is to the effect that cupric sulfide is not formed. McPherson and Henderson, "College Chemistry," page 481, state: "Cupric sulfide heated in absence of air, yields cuprous sulfide." Alexander

[1] "Laboratory Studies in Chemistry," p. 13, D. Appleton & Co.

Smith, "General Chemistry for Colleges," page 416, says: Cupric sulfide may be obtained "by cautiously heating copper with excess sulfur at 114°. At higher temperatures it gives off sulfur." Other authorities may be cited.[2] It appears therefore that cuprous sulfide is formed and the results indicated above confirm the formula Cu_2S rather than CuS as often stated in texts.[3]

With regard to possible oxidation, it may occur, but since the product which might be formed would have practically the same molecular weight as the original, there would be only a very slight difference.

$$\underset{159.20}{Cu_2S} + O_2 \longrightarrow \underset{159.14}{2CuO} + S$$

With regard to the possibility of a small core of unaffected copper, we have never found any indication of this. The product crumbles easily to bits in the fingers which it would hardly do if a fine core of unaffected wire remained.

This experiment has been done several thousand times at the English High School with average results varying but very slightly from year to year. At the proper time, the average of results obtained during the previous month of laboratory work may be made the basis for a confirmatory study of the Law of Definite Proportions.

The briefness of time required for the experiment, the generally good results obtained, the ready availability of the materials, the simplicity of the apparatus used, and the operations involved combine to make this experiment one which teachers may well consider in preparing their list of laboratory studies.

[2] Sneed, "General Inorganic Chemistry," p. 260, Ginn & Co.

[3] "Chemistry of Common Things," p. 45, Allyn & Bacon; "Chemistry for Secondary Schools," p. 174, Ambrose & Co.; "Elements of Chemistry," p. 160, Macmillan.

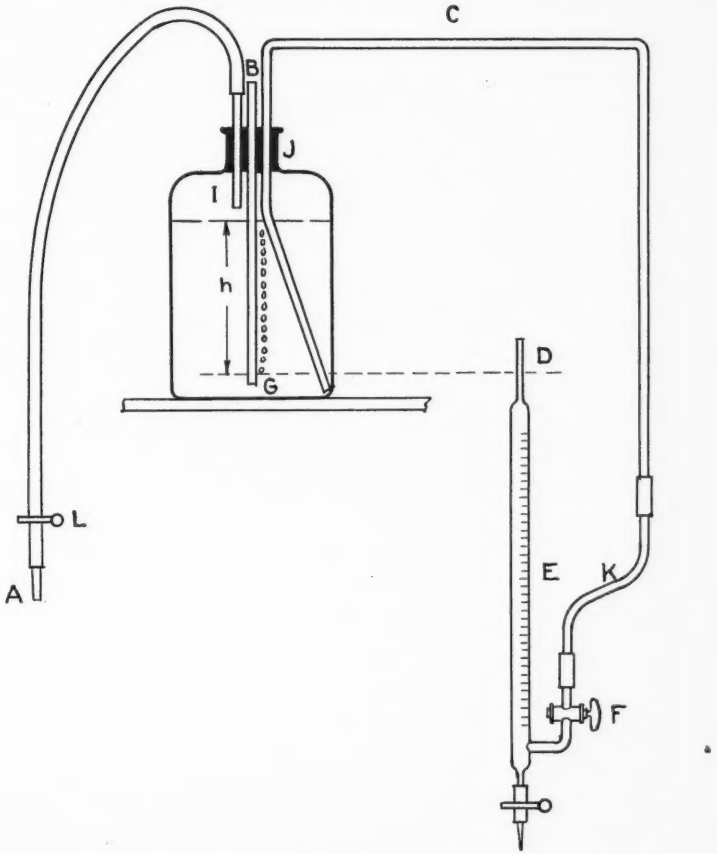
Liver Chemistry Studied to Aid Medical Science. Liver, once given away by country butchers, has climbed into a top place in the aristocracy of the meat market, and chemists are ardently wooing it to learn its secret. This is the result of the recently discovered value in the treatment of human ills, especially pernicious anemia, Dr. David Klein of Chicago told the Institute of Chemistry of the American Chemical Society recently.

At present pernicious anemia sufferers in pursuit of health have to eat liver by the pound, the speaker said, but it is the hope of the chemist to find out the particular small fraction of its mass that makes it "good for what ails you." His ambition is to get it out in pure form, analyze it, give it a long, hard name and then make it in the chemical factory. And what he hopes to do for liver he also wants to do for the thyroid, suprarenal, pituitary, parathyroid, and all the other ductless glands whose influence on our health and often on our very character is very pronounced, though as yet only partly understood.—*Science Service*

A SELF-ADJUSTING BURET APPARATUS

ROBERT C. HOCKETT, THE OHIO STATE UNIVERSITY, COLUMBUS, OHIO

In any laboratory where a large number of routine titrations are run, it is obviously of great advantage to have a buret arrangement which



will automatically fill itself exactly to the zero mark with standard solution and thus eliminate fully half of the buret readings that would otherwise be necessary. Various devices have been invented with this object but many of these require troublesome glass work for their manufacture. The apparatus shown in the accompanying diagram was worked out with the object of maintaining the utmost simplicity of design.

The tube C is simply a siphon connected through the soft rubber tube K to the buret. This soft rubber tube allows the buret to be adjusted up and down a little in position. B is an open glass tube with an opening in the lower end exactly on the level of the zero mark in the capillary tube D of the buret. A is a rubber tube connected with the air-space I and closed by a pinch-cock or screw-clamp L. To start the apparatus working, the cock L is opened and suction applied at A. The air space is evacuated and a stream of bubbles escapes at G. Then the cock is closed tightly. It is obvious that all connections in and about the stopper J must be air-tight. Now we know that the diminished pressure of air in I plus that due to the column of liquid h is just equal to the atmospheric pressure on the outside. In other words, the pressure effective at G is that of the atmosphere so that the effective surface of the liquid is that of the level of the dotted line and the effective head is only the difference in level between G and the end of the siphon tube. The latter must of course be a little below the former.

If the stopcock F is opened, the solution will flow into the buret and rise until it reaches exactly the level of G in the capillary while a stream of bubbles will meanwhile flow from G, keeping the pressure constant. There will be a very slight difference in the levels attained in D depending upon whether a bubble has just left at G or is just on the point of leaving, but the capillary is small enough to make this difference absolutely negligible for even very accurate work.

If a little cap is used to close the capillary from the air when the apparatus is not in use, it does not require cleaning for a long time and when it does, the buret may very easily be detached from the rubber tube K. If the connections are carefully made, the first evacuation is the only one necessary and the operation thereafter requires no trouble whatever. The zero mark is made preferably exactly ten cubic centimeters above the old mark in the stem so that it is easy to transpose the readings.

This apparatus has been used for two years in the standardization of student acids with a sodium carbonate solution and has given very satisfactory results.

Salt Water Is Good Hot Weather Drink. Of course, everybody drinks more water during very hot weather, but if just a pinch of salt is added it will help greatly toward enduring the heat.

Scientists investigating conditions in hot coal mines and steel plants found that the workers who succumbed rapidly when working in a temperature of about 100 degrees were able to stand it better when this small amount of salt was added to their drinking water.

At high temperatures, especially when working hard, the body gives off large amounts of water in perspiration. This is nature's way of keeping us cool. But our bodies also lose much salt with the perspiration which is what causes a large part of the physical exhaustion felt when working in hot weather. To overcome this, add a pinch of salt to your drinking water.—*Science Service*

AN EXPERIMENT IN COÖPERATIVE TEACHING

WM. LLOYD EVANS AND JESSE E. DAY, THE OHIO STATE UNIVERSITY, COLUMBUS, OHIO

The following communication is an account of an experiment in the coöperative teaching of students in first-year collegiate chemistry. We hope that the results obtained in this effort may offer some helpful suggestions to others interested in the advancement of the method used in presenting the subject of chemistry to beginners, even though these efforts may seem to be somewhat at variance with the commonly accepted traditional ways used hitherto. In this University the students in first-year work are divided into two groups: *A*, those entering with one unit of credit in high-school chemistry; *B*, those who enter without such credit. Our experiment had to do with those in the first group by reason of the increased maturity acquired through their high-school training in chemistry.

Two years ago the authors assembled those topics which dealt with the nature of matter into a brief series of successive lectures and presented the work to their classes much after the nature of a symposium. The project was repeated again last year. The interest which the historical development aroused far exceeded our expectations in the matter—in fact, our original idea was that of trying to bring the subject together in a much more connected manner than is possible in textbooks, by reason of the demands which are imposed on authors in the construction of even the best first-year treatises. Indeed, we were attempting to capitalize on the students' training in high-school chemistry in this direction as we had been doing already in other directions, especially in the laboratory.

In order to carry out the spirit of what we had in mind, it was necessary to seek the coöperation of our associates in other divisions of our department, and to invite colleagues from other departments of the University. The experiment began on the first lecture hour of our Winter Quarter, the students thus having had the Fall Quarter's work in addition to their University entrance unit in chemistry. It might be added at this point that these students had the usual treatment of the atomic theory in connection with the laws of chemical combination in the Autumn Quarter. The lectures, two per week, were given to two groups containing approximately four hundred students each. The list of topics presented this year was as follows: *1. The Periodic Law. 2. The Discovery of Radium. 3. Isotopes. 4. Atomic Structure. 5. Evidence for the Existence of Molecules. 6. The Colloidal State of Matter. 7. The Nature of Crystals. 8. Thermochemistry. 9. Matter and Energy.* Other topics might readily suggest themselves—indeed some of these might be displaced with others. Next year we hope to modify our list in such a manner that we may add

one which will attempt to give the students some idea with reference to the contribution made by astronomy to this fascinating field.

The fifth lecture was given by Dr. Edward Mack, Division of Physical Chemistry, the first and sixth lectures by Dr. J. E. Day of the Division of General Chemistry, the seventh lecture by Dr. Wm. McCaughey of the Department of Mineralogy, the ninth lecture by Dr. Alpheus W. Smith of the Department of Physics, and the others by the senior author.

At the close of the series, the students were required to make a 2500 word report on the topic, "The Nature of Matter." This report was due in three weeks after the close of the lectures.

Immediately after the series of lectures, Professors Edwin L. Beck and Sada A. Harbarger of the Department of English coöperated with the Department of Chemistry to the extent that they gave a special lecture to each of the laboratory sections with reference to the construction of a report such as was called for in the Department of Chemistry. Their aid at this point was invaluable. The Department of English accepted this report as one of the major requirements in Freshman English from all those students taking that subject also. This fact added much interest to the whole project.

In order to facilitate the work of the students, they were given a technical outline of the series of lectures and also a bibliography prepared by one of the members of the class.

It would be interesting to give the many expressions of opinion with reference to the whole project as viewed by the students themselves, but space will not permit. May we summarize the general consensus of opinion by saying that the plan seemed to have been a most profitable experiment from the student viewpoint? The topics aroused a great deal of interest among them. The libraries of the University were filled with first-year students delving into a subject which they discovered had a much wider boundary than they had hitherto supposed.

Laboratory Work

In connection with this course of lectures the students were occupied during laboratory time in a graphical study of the relation between certain physical properties of the elements and their atomic numbers. Furthermore, they spent one laboratory period in the construction of atomic models. The laboratory sections were broken up into small groups of 25 each and taken to a dark room for some simple experiments in electronics such as (*a*), the phenomena observed in the spinthariscope; (*b*) discharge of the electroscope by uranium ore; (*c*) the influence of the magnet upon the cathode rays. They were also shown the spectral lines of helium and argon.

We are offering this brief statement of our plan to our fellow teachers throughout the country in the hope that they may find the same great

interest taken in it by their students as we found with ours. Undoubtedly, the plan as here presented will have to undergo modification depending upon the institution in which it may be tried.

One of the best reports handed in will be found immediately following this article. All of the students were encouraged to illustrate their work as they saw fit, either by the use of their own drawings or those obtained from other sources. In the preparation of these reports our students were greatly aided by the articles appearing in the JOURNAL OF CHEMICAL EDUCATION in the September and November, 1927, and January, 1928, issues. At this point, it might be added that all our students were subscribers to the JOURNAL OF CHEMICAL EDUCATION during the present academic year.

THE NATURE OF MATTER*

PHOEBE ARNOLD PAINE, THE OHIO STATE UNIVERSITY, COLUMBUS, OHIO

The question of the nature of matter is a problem which has been ever present in the minds of scientific men of all ages; but it is only comparatively recently that much progress has been made in penetrating the mysteries of the structure of the material which makes up the world in which we live. For many centuries men have advanced conflicting hypotheses as to the nature of matter, but only in recent years has real experimental evidence been brought forth to prove or disprove the various theories about matter; and although chemists and physicists are still far from a complete solution of the problem, they have made and are making rapid progress.

The Structure of the Atom

Until Dalton's atomic theory was finally accepted in the early part of the nineteenth century, there were two schools of thought regarding the nature of matter. One group thought of it as continuous and divisible without limit; the other as discontinuous and, therefore, not infinitely divisible. As far back as the fifth century B.C. we find the view that matter is discontinuous defended by Leucippus and Democritus, and the theory of the continuity of matter upheld by Anaxagoras and later Aristotle. In the writings of the Latin poet Lucretius the atomistic theory is explained and supported; but throughout the Middle Ages, until the seventeenth century, it was eclipsed by the doctrine of Anaxagoras and Aristotle; and it

* This paper is published in connection with the article "An Experiment in Co-operative Teaching," by Wm. L. Evans and J. E. Day, on page 1133 of THIS JOURNAL. Miss Paine was awarded the Edward William Morley Cup by the Alpha Chi Sigma Fraternity of The Ohio State University for having the most distinguished record, out of 1600 students, in first-year collegiate chemistry for the year 1927–28.

was not until the time of Boyle and Newton that an atomic theory of matter again came to hold an important place in the minds of scientific men.

The atomic theory, however, seems to have remained purely qualitative and of very little importance in the science of chemistry until, in the Law of Definite Composition, Dalton saw a real proof that matter must be made up of atoms, and until in 1806 he gave the atomic theory a quantitative form, and showed that by means of it a number of scientific facts could be explained or predicted. He also performed a valuable service for chemistry when he made his atomic weight table. Although many of the values were inexact, still his work was so much ahead of what had previously been done that it was of greatest value in the scientific world.

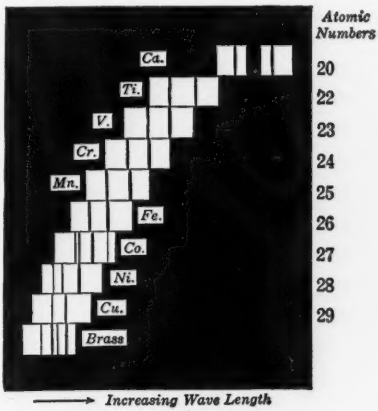
PHOEBE ARNOLD PAINE

From these somewhat inexact determinations, William Prout concluded that all atomic weights are multiples of the atomic weight of hydrogen and, therefore, whole numbers based on hydrogen as unity. This hypothesis stimulated a great deal of research, but the results all went to show that many weights are fractional; and the hypothesis was temporarily given up. The central idea, however, that of the existence of one basic substance from which all matter is made, was never abandoned; and research in recent years has shown the essential correctness of Prout's hypothesis. The steps leading up to a discovery of what is thought to be the basis of all matter are many and are deserving of attention.

Almost as soon as the atomic theory was proposed, it was felt that the various kinds of atoms could not be utterly unlike, but that there ought to be groups of elements which would show somewhat similar properties. Especially were attempts made to base a classification upon some relation to their atomic weights. In 1829 Döbereiner showed that many elements may be arranged in groups of three closely similar ones in which the atomic weight and general properties of the intermediate one are almost exactly an arithmetical mean between the other two. Later Newland developed his Law of Octaves in which he showed a relation between the atomic weights and properties of the first twenty-four elements, omitting hydro-

gen. In 1869 two distinguished chemists, Mendeléeff and Meyer, discovered, independently of each other, a relationship between the atomic weights of the elements and their physical properties and chemical conduct; namely, that the properties of the elements are periodic functions of their atomic weights. A further study of their classification reveals the fact that the elements fall naturally into two sub-groups or families; while group resemblances extend only to general chemical characteristics, family resemblances are much more marked and extend often to physical properties also.

A valuable contribution to our knowledge of the periodic arrangement of elements was made by the brilliant young British physicist, Moseley, who carried out some remarkable researches with a special kind of x-ray analysis of the elements. He found that each element gives two characteristic spectrum lines and that these lines shift through perfectly definite distances. If the elements are arranged in the order of these shifts, the order will be the same as if they were arranged according to their increasing atomic weights except in the case of argon and potassium, tellurium and iodine, and cobalt and nickel, the elements of smaller atomic number in these cases having the larger atomic weight. The order required by the atomic number is the correct one as shown by the properties of the elements in question; the reason for this change in the order can best be explained later in a discussion of isotopes. The periodic arrangement, although of great value, has its limitations; and the unquestioned irregularities which do occur in the table show us that there is still much to be learned concerning the structure of the atom.



X-RAY SPECTRA

Much of what is now known about the atom has come as a result of the study of the disintegration products of radium. The accompanying table

α-rays—helium atoms carrying a double positive charge
—speed, 20,000 miles per second
—stopped by sheet of paper
β-rays—electrons
—speed, 100,000 miles per second
—penetrate very thin sheets of metal
γ-rays—x-rays of very short wave-length
—penetrate relatively thick sheets of metal

explains the nature of the three types of rays which radium is constantly giving off; and the diagram shows how the rays are deflected in a magnetic field. By developing the photographic plate, the extent of the deflection of the α- and β-rays can be measured and the relative masses of the two kinds of particles determined. As radium is constantly giving off these rays, new products must be always forming. These products can be most easily shown in the accompanying figure, showing the last two rows of the periodic table with the positions of the disintegration products of radium, and indicating whether they are formed by the loss of an α particle, which would mean that they would occupy a place in the table in a group two lower than the preceding element in the disintegration series, or by the loss of an electron, which would place them in a group one above the preceding element.

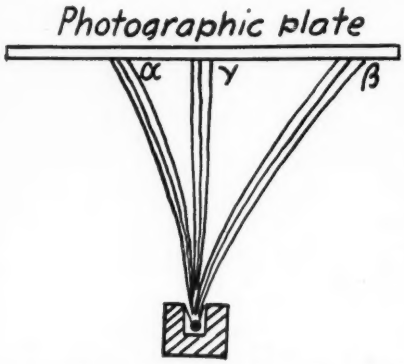
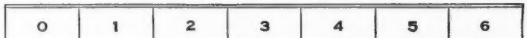


DIAGRAM SHOWING HOW THE RAYS GIVEN OFF BY RADIUM ON DISINTEGRATION ARE DEFLECTED IN A MAGNETIC FIELD

With the experimental data gained from a study of the periodic law, especially Moseley's work with atomic numbers, and a knowledge of the α- and β-rays given off by radium, physicists and chemists had a good start in their study of the structure of the atom. There are two fundamental conceptions of the atom, both still very theoretical in character. The Rutherford-



LAST TWO ROWS OF THE PERIODIC TABLE SHOWING POSITION OF THE DISINTEGRATION PRODUCTS OF RADIUM

Bohr theory, which explains radiation and spectrum lines, but which does not help with chemical combination, may be stated briefly as follows: the positive nucleus constitutes the center of the atom, and around this center the satellite electrons revolve in definite circular and elliptical orbits

which are at fixed distances from the nucleus. According to the Lewis-Langmuir theory, which explains chemical combination but which offers no suggestions to account for radiation and spectrum lines, the electrons occupy definite space relations around the nucleus in octet formation. In the inert gases, such as neon and argon, the outer octet is complete, but in

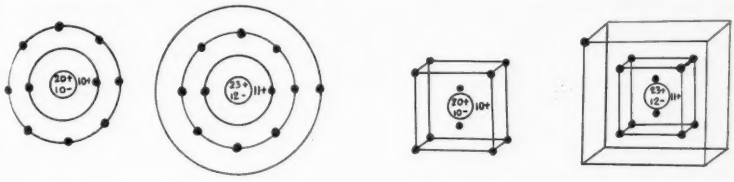


DIAGRAM ILLUSTRATING THE TWO CONCEPTIONS OF THE ATOM

the more active elements, such as sodium and potassium, the octet is incomplete. The accompanying diagrams illustrate the two conceptions of the atom. It is now possible to calculate the weight of an electron by the use of the following formulas:

$$\frac{\text{G. M. W. of H}}{\text{Avogadro's number}} = \text{Wt. of H molecule}$$

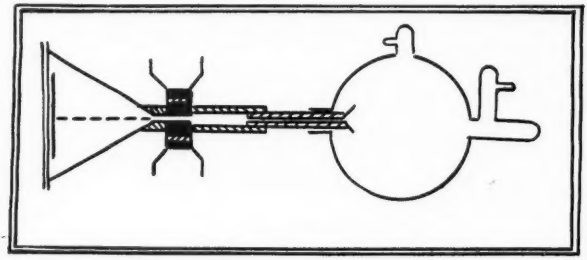
$$\frac{\text{Wt. of H molecule}}{2} = \text{Wt. of H atom}$$

$$\frac{\text{Wt. of H atom}}{1845} = \text{Wt. of electron}$$

In both conceptions of the atom the nucleus is thought of as being a complex structure composed of as many positive charges as there are units in the atomic weight and a number of binding electrons equal to the difference between the atomic weight and the atomic number; and in both conceptions the properties of the element are dependent on the charge of the nucleus as determined by Moseley in his work on atomic numbers.

It is this last fact which helps to explain isotopes. The idea of the existence of isotopes was first revealed to the chemist when the study of radioactivity showed him that a chemical element might be a mixture of two or more substances of the same atomic number but of different atomic weights. For example, samples of lead taken from thorium ore have an atomic weight of 208, from uranium ore 206, while ordinary lead has an atomic weight of 207.8. The experimental proof of the existence of these varieties of lead, identical in chemical properties but differing in properties involving atomic mass, was the first proof of the existence of isotopes. It has now been shown, chiefly through the work of the British physicist, Aston, that all ele-

ments of fractional atomic weight are mixtures of isotopes with whole number atomic weights. By means of mass spectrum analysis, in which the masses of positively charged atoms present in the electric discharge in a



POSITIVE RAY ANALYSIS TUBE

vacuum tube are examined by bending the rays in a combined magnetic and electric field so that those of equal masses fall on the same straight line, it is possible to calculate the masses of the ions. In this way it was found that chlorine, for example, consists of two isotopes of masses 35 and 37, and neon of two of masses 20 and 22. The atomic weights of the various elements calculated by physicists, from the relative proportions of their various isotopes, are in almost exact accord with the experimentally determined weights of the chemist. The isotopic notion easily explains the irregularities in the periodic table in the arrangement of potassium and argon, tellurium and iodine, and cobalt and nickel.

Since the weights of all isotopes are whole numbers, it seems very probable that the basic idea of Prout's hypothesis is, after all, correct. If four hydrogen atoms could be packed so closely together that their electrons would all fall to a very low energy level and thus radiate a large quantity of energy, a helium atom of atomic weight 4 ought to be formed; and the 0.032 unit which constitutes the relative difference in weight between four hydrogen atoms and one helium atom ought to be converted into energy. At present this is only an hypothesis, but from our present knowledge it seems very likely that it is a true one.

The discovery of isotopes, then, has accomplished four very significant things: first, it has enabled scientists to count with certainty the exact number of positive and negative particles inside every nucleus; second, it has resurrected the discredited and amazingly simple Prout hypothesis that the masses of all atoms are exact multiples of a single primordial atom; third, the failure of hydrogen to fit exactly into the scheme of whole number atomic weights constitutes excellent evidence for the Einstein conclusion as to the interconvertibility of mass and energy; and fourth, the difference in stability (decay time) of radioactive isotopes suggests new possibilities

in the reading of the structure of the tiniest organism yet found—the nucleus of the atom.

The Structure of the Molecule

Not only have scientists been interested in the structure of the atom, the smallest particle of matter which takes part in an ordinary chemical change, but also they have studied the nature of the molecule, the smallest particle with which physical phenomena are concerned. The molecular theory of matter was first formulated to account for the properties of gases such as those involving volume, temperature, pressure, and the rates of diffusion; but in more recent years more definite evidences for the existence of molecules have been discovered. The facts of the radiometer help to substantiate a belief in the existence of molecules. It is difficult to explain the revolution of the arms if it is not assumed that air consists of molecules; the blackened sides of the veins absorb radiant energy from light or heat and become heated; thus the molecules striking these faces acquire greater velocity than those striking the white faces, and rebound with greater energy, sending the white faces forward. In a study of Brownian movement it is also possible to show evidence for the existence of molecules; the irregular zig-zag motion of microscopically fine particles suspended in a liquid is caused by the collision of rapidly moving molecules with these particles. Another evidence for the molecular structure of matter is seen in the facts from the spreading of oil films. Vegetable and animal oils, the molecules of which have a chain structure with a soluble —COOH group at the end, spread over the surface of water until all the —COOH groups are dissolved. If the volume and area of the film are known, the depth can be calculated; and the depth is equal to the length of the molecule. A film which consists of but one layer of molecules possesses different physical properties than does a thicker film, and this fact shows that the oil film has not a continuous homogeneous structure. Probably the most positive evidence for the existence of molecules lies in the facts revealed by the x-ray. Through an x-ray study of crystal structure, evidence has been brought forward for the existence of molecules, especially in the non-polar compounds which almost always show on x-ray analysis a molecular grouping of atoms. The polar compounds, such as common salt are probably ionized even in solid form and their ions held together by electrostatic attraction. By x-ray analysis it is possible to calculate the size of the various molecules. There are many other reasons for believing in the existence of molecules, but the ones I have mentioned give an idea of the

RADIOMETER

various ways by which the theory of the molecular structure of matter is substantiated.

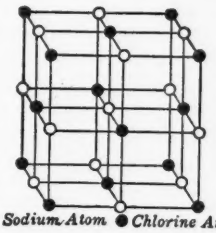
Larger than molecules, but still too small to be seen even through the most powerful microscope, are minute particles which occur only dispersed in some other medium and which are known as matter in the colloidal state. These particles are non-geometric clumps of molecules and are so small that they cannot be filtered by ordinary means from the medium in which they are dispersed, although they are unable to pass through a semi-permeable membrane. As a result of this fact colloidal dispersions can be separated from regular solutions by a process known as dialysis. In a general way it may be said that colloidal particles vary in diameter between $100\mu\mu$ and $1\mu\mu$, but these limits are purely arbitrary.

The presence of colloids may be detected in several ways. One of these ways is by the Tyndall effect; if a beam of light is passed through a colloidal dispersion, the tiny particles reflect the light and a bright path of light known as the Tyndall effect is seen in the dispersion. The introduction of the ultra-microscope by Siedentopf and Zsigmondy enables one to detect the presence of colloidal-sized particles by observing the bright specks of light reflected from them. Brownian movement in colloidal dispersions can be observed through the ultra-microscope.

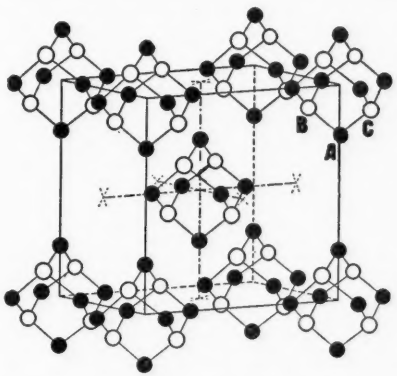
Since the colloidal state is a state of very fine subdivision, the extent of the surface exposed is very large relatively to the total volume of the matter. Consequently, in the production and characterization of colloidal systems, adsorption plays a part of the highest importance. By the adsorption of ions from the dispersion medium or from electrolytes present in solution, the colloidal particles acquire an electric charge. Adsorption of the dispersion medium as a whole may also take place to a greater or lesser extent, whereby variation in the general behavior of colloids may be brought about. In the case of the so-called suspensoid colloids, the dispersed particles may adsorb none or practically none of the dispersion medium, in which case they exist as suspended particles, the stability of which is due mainly to their electric charge and their Brownian movement. In the case of the emulsoid colloids, such as solutions of gelatin and starch, adsorption of the dispersing medium itself takes place, and the stability and properties of such a colloidal solution are due to the adsorbed dispersion medium as well as to the electric charge on the particles. If the electric charge on a suspensoid colloid be neutralized, either by an electrolyte or a colloidal particle of opposite charge, agglomeration of the particles takes place followed by precipitation. Emulsoid particles, however, are much less sensitive to electrolytes and are often added to suspensoid colloids to keep them from precipitating. Such colloids are known as protective colloids. The study of colloid chemistry is becoming in-

creasingly important as chemists are realizing more and more how many substances exist in nature in the colloidal state.

Another form of matter which occurs to a very large extent in nature is the crystalline; indeed, all matter in the solid state is in the form of crystals, though some of these are so minute as hardly to appear crystalline in structure. All perfect crystals show perfect symmetry; some are symmetrical by reflection and some by rotation. From a knowledge of the outward form of crystals, scientists gained an idea of the internal structure which was later substantiated by evidence from the x-ray field. It has been shown that the properties of crystals are vectorial; for example, the conductivity of heat or electricity by a crystal varies according to the direction they are passed through the crystal; but the properties are always the same in parallel directions. Since this is true, there must be parallel orientation of the atoms within the crystal. This idea is further borne out by the facts of cleavage—crystals always break in parallel planes. But it was by evidence from x-rays that a real advance was made in the study of crystalline structure. Crystals consist of a homogeneous assemblage of particles —atoms, ions, or molecules— which are arranged in certain definite ways along straight lines and in parallel planes. In the sodium chloride crystal the uniformly spaced atoms may be thought of as either atoms or ions, but recent work of the physicists makes it seem extremely probable that they are ions. In the diagram of the $C_6H_{12}N_4$ crystal it may be seen that such crystals consist of molecules regularly spaced rather than atoms or ions. Since the rows in a crystal are about the right distance apart to act as a diffraction grating for x-rays, photographs may be obtained by passing a beam of x-rays through a thin crystal and catching the emergent beams on a photographic plate. An effect such as is shown in the above diagram will be obtained. The small dots are

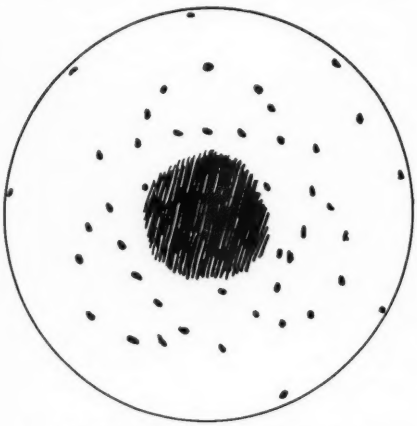


ARRANGEMENT OF SODIUM (WHITE) AND CHLORINE (BLACK) ATOMS IN NaCl CRYSTAL



ARRANGEMENT OF CARBON (BLACK) AND NITROGEN (WHITE) ATOMS IN $C_6H_{12}N_4$ CRYSTALS

produced by the interference and reinforcement by the atoms in the crystal of the x-rays; and their systematic arrangement corresponds to the symmetry of the crystals. By proper mathematical analysis it is possible to reconstruct the space relations of the atoms and layers of atoms in a crystal from such photographs; and such analysis substantiates the fact that the outward form of a crystal is evidence of its internal structure.



LAUE X-RAY PHOTOGRAPH THROUGH BASAL PLANE OF PENNINITE

The Nature of Solutions

In the discussion of atoms, the structure of an element was shown, and in the discussion of molecules, the nature of a compound; solutions are a third class of substances which are homogeneous in character and which lie midway between compounds and mixtures. Of solutions of non-electrolytes little need be said further than the fact that molar weights of such compounds produce the same lowering of the freezing point and vapor pressure, raising of the boiling point, and change in osmotic pressure when dissolved in the same volume of solute. This fact is really another evidence for the existence of molecules, since it is seen that the above-mentioned effects are dependent upon the number of molecules. It was observed, however, that solutions of electrolytes showed greater changes in these constants than those of non-electrolytes; this fact combined with the simplicity in the chemical action of electrolytes in solution, the law of thermoneutrality, and the facts of electrolysis, especially Faraday's law which states that when one gram-atomic weight of any univalent metal has been deposited at the cathode a definite quantity of electricity has been carried through the solution, suggested the Arrhenius theory of ionization. This theory is still used just as it was formulated by Arrhenius except for the fact that physicists now have reason to believe that electrolytes are ionized even in the solid state, and that when they go into solution, the ions are merely loosened and are free to move.

The Relation between Matter and Energy

Until recent years matter and energy were regarded as two separate entities which could in no way be converted one into the other; and just

as matter was once thought of as continuous, so energy until comparatively recently has been thought of as continuous. Physicists have now found reason to believe in the atomistic character of energy; and the quantum theory of energy was rather lately formulated. The quantum theory assumes that matter is made up of units (similar to atoms of matter), or at any rate that it is communicable only by these units; the unit of energy is proportional to ν, the frequency of the radiation, and equal to $h\nu$, where h is Planck's constant. This theory, which originated in an attempt by Planck to explain heat radiation, has now been extended so that it explains, to a great extent, specific heat and the emission and absorption of radiation including spectra. In a discussion of the nature of matter the most important application of the quantum theory is its relation to spectra. More than thirty years ago, Rydberg in his famous investigation of the line spectra was able to analyze the spectra of many of the elements; he found that the frequencies of a line spectrum could be represented by an equation of the type, $\nu = Rc\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$, where c is the velocity of light ($c = 3 \times 10^{10}$ cm./sec.); while n takes a series of successive integral values; R, generally called the Rydberg number, is constant throughout all the spectra. According to the quantum theory an electron in falling from one orbit to an inner one of smaller energy loses a definite quantity of energy which is emitted as monochromatic radiation; the frequency of the radiation is governed by the quantum laws; *i. e.*, $h\nu = E_1 - E_2$ where E_1 and E_2 are the energies in the initial and final orbits. This offers a basis for interpretation of line spectra for the spectral terms appearing in this relation can be identified with the energy values E_1 and E_2 divided by h. This view of the origin of the spectrum has been found to agree with the experimental results gained in the excitation of radiation. This is shown in the discovery of Franck and Hertz relating to impacts between free electrons and atoms. They found that an energy transfer from the electron to the atom can take place only in amounts which correspond with energy differences of the various orbits as computed from the spectral terms.

The existence of a relation between matter and energy makes possible a more complete explanation of many chemical facts. For example, exothermic and endothermic compounds can be explained satisfactorily if it is assumed that in the formation of exothermic compounds the electrons drop to a lower energy level and, therefore, give off energy, while in endothermic compounds the electrons move to a higher energy level and absorb energy. The existence of allotropic forms of the same element can also be explained if one realizes that as the electron moves toward the nucleus, the internal structure of the atom, and therefore its outward appearance, is changed. An energy change also occurs which accounts for the fact

that allotropic forms of the same substance have different energy contents.

When one thinks of the many valuable and interesting discoveries that have been made regarding the nature of matter and of the multitude of baffling problems concerning it that are yet to be solved, it is small wonder that physicists and chemists alike are devoting so great a part of their time to delving into the mysteries of the material which makes up our universe. Certainly we shall watch with interest the further developments on this subject which are sure to come in the near future and which will undoubtedly reveal much of theoretical and practical importance.

Source of Information

Lectures

The Periodic Law	Jesse E. Day
Radium	William L. Evans
Isotopes	William L. Evans
Atomic Structure	William L. Evans
Evidence for Existence of Molecules	Edward Mack, Jr.
Colloids	Jesse E. Day
Crystals	William J. McCaughey
Thermochemistry	William L. Evans
Matter and Energy	Alpheus W. Smith

Magazine Articles

JOURNAL OF CHEMICAL EDUCATION

Electricity and Matter	William S. Johnson, **4,** 1088–97 (Sept., 1927)
X-Rays and Chemistry	Robert L. Hershey, **4,** 1335–56 (Nov., 1927)
Atoms, Molecules, and Ions	James B. Conant, **5,** 25–35 (Jan., 1928)

Scientific American

On the Trail of the Molecule	S. R. Williams, **137** (Oct., and Nov., 1927)
Building Blocks of the Universe	B. S. Hopkins, **136** (Feb., 1927)

Books

A Course in General Chemistry — McPherson and Henderson
Chapters VII, XII, XIV, XVII, XXI, XXVII, and XXXI

The Encyclopaedia Britannica

Eleventh Edition	Articles on the Atom, the Molecule, Elements and Matter
Twelfth Edition	Articles on the Constitution of Matter, Atoms, and Radioactivity
Thirteenth Edition	Articles on the Quantum Theory, Atoms, Crystallography, Radioactivity, Colloids and parts of the articles on Chemistry, Physical Chemistry, and Physics

Diagrams

Atoms, Molecules, and Ions—JOURNAL OF CHEMICAL EDUCATION
X-Ray Spectra
Last Two Rows of Periodic Table
Arrangement of Carbon and Nitrogen Atoms in $C_6H_{12}N_4$ Crystal

A Course in General Chemistry
Deflection of α, β, and γ Rays
Apparatus for Mass Spectrum Analysis
Encyclopaedia Britannica—Article on Crystallography
Sodium Chloride Crystal
Laue X-Ray Photograph

Molds Cheating Lemons Out of Their Jobs. How a common black mold, long known as a spoiler of food, has been drafted for the manufacture of citric acid, long a monopoly of lemons and other sour citrus fruits, H. T. Herrick of the U. S. Department of Agriculture reported before the American Chemical Society Institute.

At least as far back as Noah's famous spree, Mr. Herrick reminded his audience, man has used fungi for the production of desired chemicals; for the yeasts that ferment sugar to alcohol are fungi. The molds, belonging to a different fungus family, have also served mankind in the making of such things as cheese, for the green streaks in prime Parmesan are really moldy spots. But it is only lately that molds have been deliberately set to work on sugar, and their possibilities as chemical servants are only beginning to be realized.

The principal industrial exploitation of the appetite of a mold for sugar at present is the manufacture of citric acid. This has received a special stimulus from the imposition of an export tax by Italy on its citrate product, derived at present wholly from lemon culls. Since the whole soft-drink industry depends on citric acid, and a great deal is used in flavoring extracts as well, the Italian export duty may have almost the same effect on the infant American acid-from-mold industry as a protective tariff.

At present the sugar from which the mold makes citric acid is the familiar cane sugar or sucrose. This is relatively expensive, and Mr. Herrick and his assistant, O. E. May, a e now hard at work in the hope of producing citric acid from the action of mold on the cheaper corn sugar or glucose. Hitherto this has not been possible because of the impurities present in commercial glucose, but a product of high purity is now available.

Citric is not the only acid that can be produced by the action of molds on sugar. There are many different kinds of mold, and many varieties of sugar, and the combinations possible are almost infinite, according to Mr. Herrick. Such acids as oxalic, malic, lactic, and succinic are now known to be produced by molds, and the investigation has not proceeded very far.

One acid, which has hitherto been so rare that it is listed at over $100 a pound, has been produced by Mr. Herrick and Mr. May in the government laboratories at about thirty-five cents a pound. This is gluconic acid, which is the result of the action of one species of mold on glucose. Very little is known of what gluconic acid may be good for, because its high price has hitherto practically prohibited experiments, but an investigation of its industrial possibilities may now be expected.—*Science Service*

American Scientists Visit British Shrine. Rothamsted, where the oldest and in many respects the greatest of the world's agricultural experiment stations is located, is becoming more and more the Mecca of American scientists on their European travels. The place of especial interest is the series of culture plots laid out 85 years ago by Sir John Lawes and Sir J. H. Gilbert, which have been under constant experimentation and observation ever since. These constitute the original model of all agricultural experiment stations in Europe and America.—*Science Service*

The Chemistry Student

WHY STUDY CHEMISTRY?

OTTO REINMUTH, ASSOCIATE EDITOR

It is only natural for a student to ask himself when he begins the study of chemistry, "Just why am I taking this course?" "What do I get out of it?" And it is a good thing for him to ask these questions about any subject. If he can answer them satisfactorily or if he can obtain satisfactory answers to them, he is prepared to get a good deal more out of the subject than he would by passively and unthinkingly accepting what the instructor passes out to him.

Of course one expects a certain number of scholastic credits for a course successfully completed, but that is only an incidental and secondary consideration. We all realize that credits are given merely as a measure—and a rather imperfect measure, at that—of the real objective to be accomplished. Otherwise it would save trouble and expense for everybody concerned, to act upon the suggestion of the wit who recommended that a high-school diploma and a college degree be conferred upon every American child at birth.

One may say that he has elected the course because it interests him or because he believes that it will give him information that can be applied to something else in which he is interested. These are excellent reasons, and, no doubt, sufficient in themselves. Yet we devote time and money to many things which "interest" us without conferring upon us any solid or lasting benefit. It is altogether to the point to consider whether or not the study of chemistry has any permanent value aside from the interest it may hold.

If the course has been prescribed and the student must pass it to graduate, he has every right to ask whether the time he spends in it is so much dead loss which he must suffer to fulfil an arbitrary requirement or whether the educators really have some sound reasons for believing that it will do him good.

It is rather the fashion nowadays to attack the educators. No one can deny that they make mistakes and there are times when some of them appear utterly unreasonable to other people. Yet they do deserve to have at least this good word said for them—that they are for the most part serious and conscientious folk who do the best they can according to their lights. And if their lights are sometimes less than dazzlingly bright, it is not because they fail to burn the midnight oil over their problems. Perhaps we had better hear their side of the case. In legal phraseology, let them show cause why chemistry should be included in the curriculum.

Various individuals have drawn up various more or less detailed lists of reasons why science in general and chemistry in particular should be taught in our schools and colleges. Usually they call them lists of objectives—that is, things which teachers should endeavor to do for students, or to help students do for themselves, through these subjects. Most of the reasons or objectives which apply to chemistry also apply to science in general.

Briefly, we may boil them down to this—that science properly taught and intelligently studied should:

1. Give the student a broader outlook upon the universe in which he lives and upon the life which he leads in it;

2. Help him to live more satisfactorily,

(*a*) By furnishing him with facts which will answer many of the questions which confront him in every-day life, and

(*b*) By training him in habits of thought which will help him to solve problems for which no ready-made answers exist.

In attempting to summarize, we have been forced to clothe these ideas in rather shop-worn phrases. Let us try to get behind these vague and moth-eaten generalities and find out more definitely what they really mean. That is not altogether easy, especially in relation to our first topic.

The man who has been trained in science realizes that his ideas in general have altered; that he has a different mental attitude toward the world and toward life; that he sees things in a new light and in new relations to each other. He finds it hard to analyze the changes which have taken place in his way of thinking or to ascribe them to specific things which he has learned. He feels, however, that his present state of enlightenment is more satisfactory than his former state of comparative ignorance and he sums it up by saying that his outlook has been broadened. He feels that the changes which have taken place in his mental attitude are hard to explain to one who has not experienced similar changes—in short, that "the goods must be sampled to be thoroughly appreciated"—and he is tempted to beg the question by saying, "Try it and see."

But that is hardly satisfactory to one who is trying to get information in advance. Perhaps we can throw some light on what such a man would like to say, if he only knew how, by considering a comparison. We sometimes speculate on what George Washington would think if he were to revisit in the flesh the country which he is credited with having fathered—if he could view the countless inventions which have become commonplaces of every-day existence since his time. Or we sometimes try to imagine the mental reactions of a savage turned loose on Broadway. There can be no doubt that the effects on the two men would be quite different. In fact, the two cases would have but one factor in common. Each of the two men would see a myriad things entirely foreign to his previous experience, but there the similarity would cease. The savage would probably attribute the wonders

he observed to magic, and his natural emotion would be fear. He would be mentally overwhelmed. It would be almost useless to attempt to explain anything to him. Neither his mental attitude nor the knowledge which he already possessed would fit him to understand our explanations. They would only bewilder him the more. George Washington, on the other hand, would be amazed without doubt, but he would not be overwhelmed. He would not ascribe any of the astonishing sights before him to the mystical workings of some fearful supernatural power. His first reaction would be one of eager curiosity. He would want to know what new scientific discoveries had made these things possible and how men had applied them to obtain such results.

One may object that the comparison between the savage and George Washington is scarcely a true parallel for a comparison between the civilized man of today who has never studied science and the man who has. Even though one never formally studies science he "picks up" a great deal almost unconsciously—certainly enough to banish a belief in magic.

That is true. In order to emphasize our point we have purposely chosen an exaggerated example. And yet the exaggeration is not so great as it might at first appear. After all, how many of the devices which he sees and uses and accepts calmly as a matter of course, does the untrained man really understand? Is not his acceptance more a matter of familiarity than of understanding? When he hears that a physiologist has discovered a new fact about nutrition or that a chemist has produced a new dye or a new plastic he knows that there is no magic in it for the same reason that *we* know there is no real magic in the tricks of the stage magician—he doesn't believe in magic. But the whole thing is quite as much a mystery to him as the vaudeville performer's tricks are to us. How much more satisfying to know just how the thing is done!

The average man knows that the dry cells which operate his door bell gradually run down; that they must eventually be thrown away and replaced by new ones. He knows that his automobile battery, on the contrary, can be recharged, but he does not know why. He knows that his automobile battery needs water once in a while and that distilled water or rain water should be used rather than tap water. He knows that the hydrometer will tell approximately how far his battery has "run down." In short he knows enough for all ordinary practical purposes, but he has not the satisfaction of knowing the reasons for what he does.

He follows certain directions because he knows that things go wrong when he doesn't, just as a child may obey certain arbitrary commands in order to avoid punishment. How much more pleasant it is to be given good reasons for doing things than to be ordered to do them or suffer punishment. We are all the children of Nature. Whether her laws compel us arbitrarily or reasonably depends upon how well we are able to understand their work-

ings. The child who is treated reasonably has a pleasanter time than the one who is ordered about—he is able to do what he must do coöperatively rather than rebelliously. It is so with the man who understands something of the laws of Nature; his attitude toward life is different.

We have devoted a proportionately large amount of space to the discussion of our first topic—partly because it is one angle of the matter which is too often neglected, and partly because (as we have already remarked) it is something which may be easily seen on looking back, but which it is difficult to explain beforehand.

The first part of our second topic needs but little amplification. When we need legal advice we see a lawyer; when we require medical services we call a physician; likewise we can submit chemical problems to a public analyst or a consulting chemist. But in all these cases we find it highly convenient to be jacks-of-all-trades to a certain extent. We all know some law which we do not need a lawyer to tell us. We know for instance the traffic regulations and the simpler forms of contracts, like notes and leases, etc. We know, or should know, the simpler rules of health; we can disinfect minor cuts and treat sprains and bruises, if they are not too serious. We *should* be able to apply first-aid measures, even in serious cases, until a doctor arrives. Just so, we should be able to solve simple chemical problems for ourselves.

Finally, the scientist must have or acquire certain characteristics and certain habits of thought. The "outward manifestation" of these "inward graces" is the scientific method. Although these characteristics and habits are absolutely essential to the scientist they are also useful and desirable in every-day life. The educators hope that the study of science may demonstrate to the student their desirability and, to a certain extent, help him to acquire them.

Milton Fairchild of the Character Education Institution lists the characteristics of the scientist as follows:

1. Sincere and open-minded; not diverted by personal interests.
2. Alert and alive to truth, vital; not complacent.
3. Poised; not excitable, hysterical, or melancholy.
4. Discerning and thorough; not superficial.
5. Accurate; not indefinite.
6. Inventive and constructive; not lacking initiative.
7. Independent; not suggestible.
8. Thoughtful and persistent; not merely impulsive.
9. Industrious and energetic; not lazy and dilatory.
10. Executive; not haphazard.
11. Purposeful; not led merely by likes and dislikes.
12. Self-confident; not timid.

If the scientist must have certain virtues it follows that there are certain faults and weaknesses which he must avoid. Mr. Fairchild calls these "intellectual immoralities" and lists them as follows:

1. Carelessness in observations, "sloppy work."
2. Inaccuracy in determining units to be counted in statistical research.
3. Slovenliness in logic, fantastic explanations.
4. Generalizing beyond one's data.
5. Confusing opinions with knowledge.
6. Confidence in the results of research in disregard of weakness in proof and verification.
7. Contentment with "discussion."
8. Poor judgment in research plan and procedure.
9. Wavering interest, flitting attention, attracted by peculiar superficialities.
10. Egoism allowed to crowd one to the invention of "new" theories for personal distinction.
11. Inventing interesting theories for the sake of selling them in books, articles, lectures, and conversation.
12. Pride allowed to result in persistent belief in a theory for which one has been given credit.
13. Formulating an hypothesis on weak bases of facts, and then becoming blind to facts in opposition.
14. Emotionalism during research, "I believe" instead of "I have proved."
15. Adjusting theories to popular likes and dislikes.
16. Opposition to proof of another's theories because of jealousy.
17. Opposition to a theory merely because of ignorance and stupidity, "I cannot see how."
18. Rushing into print with a report of research work that justifies no conclusions.
19. Degenerating into a propagandist of an unproved hypothesis, instead of being true to the research purpose of discovering the truth.
20. Cowardice in supporting a verified generalization because it is unpopular and conflicts with selfish interests.
21. Impatience, unwillingness to proceed step by step through a research.
22. Indulgence in dense verbiage for the sake of appearing superlearned.
23. Ignorance of the mechanism of instruments of precision, which results in their use when out of order.
24. Popularizing tentative generalizations for the sake of personal publicity.
25. Resort to the authorities, or to sarcasm and ridicule, against data, arguments and verifications.

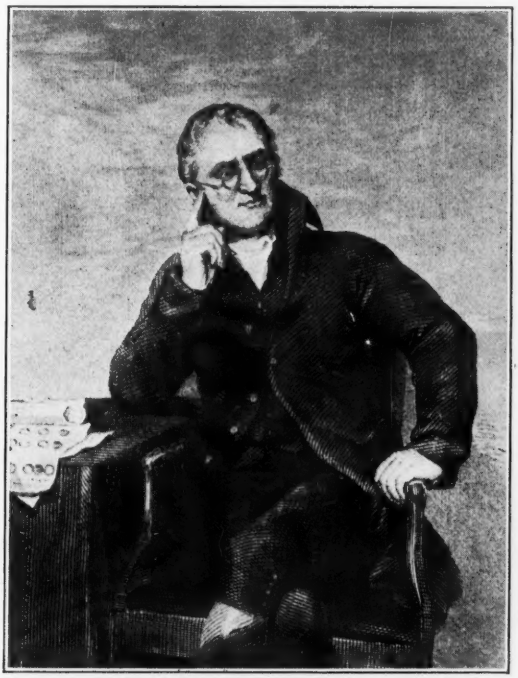
It is evident that the "scientific method" of thought and action is applicable not only to science but to all the affairs of life. This is the thing which the student should make the most conscious effort to get out of his course. If he truly acquires the scientific method, the other benefits to be derived from a study of science will come to him almost automatically as by-products of the process.

THE STRUCTURE OF MATTER. I. HYDROGEN AND OXYGEN

OTTO REINMUTH, ASSOCIATE EDITOR

No doubt the reader is already fully aware of the distinctions between facts, laws, hypotheses, and theories. It may not be out of the way, however, to point out that hypotheses and theories perform a double service. First, they may be considered as attempts to roughly approximate the

actual truth. We begin with a number of more or less unrelated facts and we attempt to formulate a theory or hypothesis which will take account of them all and bring them into closer relationship with each other. In other words we sketch a rough picture of things as they appear to us. If we have

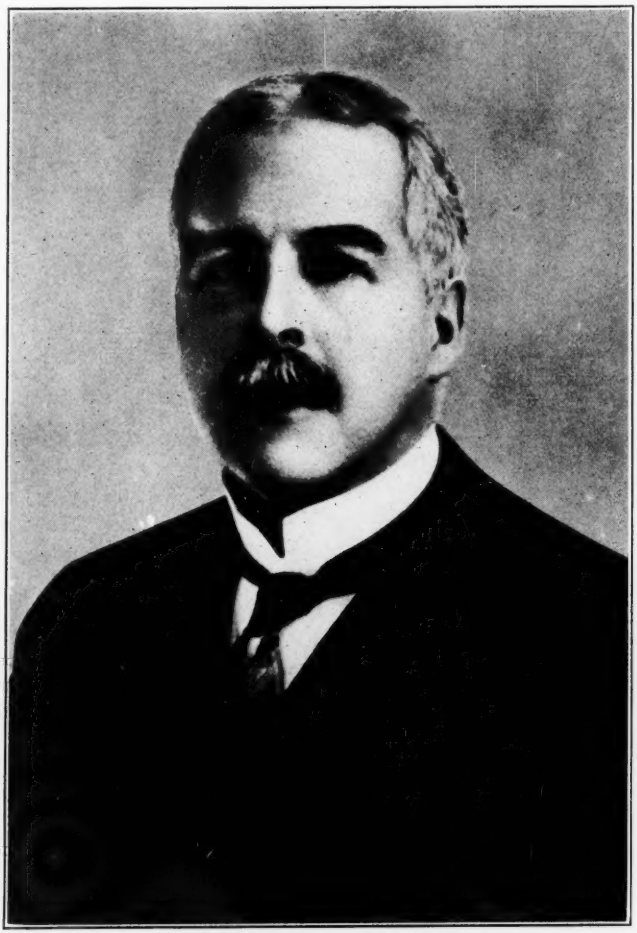


JOHN DALTON, WHO INTRODUCED THE ATOMIC THEORY INTO MODERN CHEMISTRY

He published the first table of "atomic weights." Most of his weights were incorrect, partly because he was not a skilful experimenter and partly because he was unable to distinguish between "atomic weights" and "equivalent weights." This confusion also detracted from the usefulness of his theory and hindered its acceptance by other chemists. Cannizzaro, a young Italian, was finally able to clarify the matter and so prepare the way for a rapid advancement in chemistry. Articles on Dalton and his work may be found in the May, 1926, and January, 1927, numbers of THIS JOURNAL. For Cannizzaro, see the December, 1926, and July, 1927, numbers.

had enough facts to start with, and if we have interpreted them intelligently, that picture bears some resemblance to the reality. We then set out to discover new facts with which to test our theory. If they agree exactly, well and good; if not we must alter our picture somewhat. Perhaps you

have watched a lightning sketch artist on the vaudeville stage. Sometimes he fools you by apparently starting to draw one thing and then, by adding a



DR. GILBERT N. LEWIS

Dr. Lewis has done more, perhaps, than any other one man in the application of theories of atomic structure to the interpretation of chemical phenomena.

few rapid strokes, changing it into something entirely different. Occasionally, the same thing happens in science. Sometimes new facts make

us alter our theories so much that one would hardly recognize them as the ones we started out with. As a rule, however, the alterations are not so great. They usually consist in adding details and refinements to our original outline.

That is one aspect of the theory or hypothesis. One may adopt a different point of view and say that the hypothesis is a working tool or plan. Sometimes even after we know that our first picture is not a very good likeness, we find it quite useful as a plan to go by. The drawing of a radio hook-up is not a very good picture of a completed radio set, but it tells the experimenter most of the things he needs to know in putting a set together, and it does not confuse him with a lot of unnecessary details. Just so, some of our scientific theories are often still useful even though we know them to be poor pictures of the ultimate reality.

This fact applies to our theories of the structure of matter. To fully appreciate the situation it is necessary to recall that the subject of the structure of matter was at first attacked separately from entirely different angles by the chemists and the physicists. Each class was most interested in the aspect of the matter which lay closest to its own experience. One is reminded of the fable of the blind men who severally laid hands on different portions of an elephant and ever afterward carried on a spirited discussion in which they could come to no agreement about what an elephant was really like. Now we who have had the advantage of seeing elephants know that each of the blind men was right so far as he went. The only trouble was that none of them had gone far enough to form a complete mental picture.

But the chemists and the physicists have not been so foolish as the blind men in the fable. Although their first ideas as to what an atom is like were quite different, they did not begin to quarrel about it. They set out to compare notes and to piece together a picture which should be nearer the truth than any they had to start with. This is still going on; new facts are being sought and found, and we are gradually working toward an idea of what the atom is really like.

In the meantime, however, we are able to make use of a picture, which does not include or explain many of the facts which the physicist has discovered, when we are dealing with purely chemical matters. In fact we find it an advantage not to encumber ourselves with some of the more exact details of the constitution of the atom. Hence, it should be understood that the description of the atom which we are about to consider is not a complete or accurate picture but merely a sketch which we shall find useful in explaining chemical facts. The diagrams which we shall use are probably not nearly as good pictures of atoms as the radio hook-up drawings are of radio sets, but they will serve our purpose.

We may begin with a few statements which are supported by such a mass

of circumstantial evidence that we are quite safe in calling them facts—indeed, it is hard to imagine how they could be questioned.

1. *Matter is made up of atoms.*

2. *Atoms are, in turn, built up of units which we call protons and electrons.*

3. *Electrons are electrically "negative," protons are electrically "positive." Their electrical charges are equal.*

4. *Every atom contains an equal number of positive and negative charges, so that the complete atom is electrically neutral.*

5. *The atom owes practically all of its weight to the positively charged protons.*[1]

6. *The protons are concentrated within a relatively small space at the center of the atom.*

7. *Something more than electrical neutrality is necessary to assure the stability of an atom.* Certain combinations and arrangements of protons and electrons are so stable that it is very difficult to disturb them; other combinations are so unstable that they cannot exist—at least they have never been discovered. There are varying intermediate degrees of stability.

8. *Atoms of the same element have the same numbers of electrons and protons;*[2] *atoms of different elements have different numbers of protons and electrons.*

With these facts in mind let us see what details we can add to account for the chemical behavior of atoms. Naturally, we think first of the simplest combination possible—that of one proton and one electron. We find that this combination corresponds in every way to the element which we know as hydrogen. We shall not pause to discuss the chemical properties of hydrogen just yet. We know of no elements which contain only two or three protons, so let us proceed to the combination of four protons and four electrons. We have said that the protons are found to be concentrated near the center of the atom. Now one would naturally suppose that positively charged bodies would repel each other and that they would tend to scatter apart rather than to concentrate. What holds the protons together? One possible explanation is that some of our electrons are also present in this small space at the center of the atom and that they serve to hold the protons together. Let us accept this explanation tentatively until we discover some new fact which would cause us to think differently. The electrons and protons which occupy the small space at the center of the atom we shall call the nucleus. Then if we represent protons by plus signs and electrons by minus signs we can diagram one possible structure for the 4-proton atom as

[1] The mass of a proton is about 1846 times the mass of an electron. In a later article we shall discuss just what is meant by the mass of a proton or an electron and how these minute units are "weighed."

[2] There is a minor exception to this statement, which need not concern us now but which we shall encounter later in the study of "isotopes."

in Figure 1. This is a crude schematic representation of the present idea of the constitution of the helium atom.

Without examining in detail all the reasons which have led chemists to adopt certain conclusions let us see what additional postulates or assumptions have been made and then proceed to test them by seeing how they work out in practice. We can sum up briefly the ones which we need to go on with as follows:

1. *Electrons are arranged in layers or shells around the nucleus.* Here it should be understood that when we talk about the "position" of an electron we are speaking rather loosely for it is highly improbable that we have a right to consider the electron a particle at all, and it is certain that electrons cannot be considered as fixed, like raisins stuck on the outside of a pudding. However, we do know that each electron produces effects within a certain limited space. That space may be the "mean position" of an orbit in which the electron spins or it may be something even harder to define. But that space (whatever it may eventually turn out to be) is the thing in which we as chemists are primarily interested, and it is the thing which we shall refer to when, for purposes of convenience, we speak of the position of the electron.

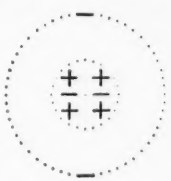


FIGURE 1

2. *The maximum number of electrons for the first layer outside the nucleus is two, and that is also the number which gives the most stable configuration.*

3. *The maximum (and the most stable) number of electrons for the second layer is eight.*

4. *Atoms tend toward the most stable possible configuration.* That configuration may be reached either through the gain of electrons, resulting in the completion of a partially filled outside layer or shell, or through the loss of electrons, resulting in the removal of a fragmentary layer. In consideration of the electrostatic attraction between the negative electrons and the positive nucleus, it has been argued that we are never correct in saying that an atom has a tendency to lose electrons. Each atom has a tendency to hold its own and even to attract more electrons. In some the tendency is stronger than in others. Thus an atom does not under any ordinary conditions cast electrons off into space—it loses them only in the presence of another atom which attracts them more strongly. The net result is that some atoms which have a very weak attraction for electrons habitually lose them; others with a very strong attraction for electrons habitually gain them; while still others, intermediate between these extremes, sometimes lose and sometimes gain.

This characteristic which we have just been discussing and which we have loosely defined as the tendency to attain a state of maximum stability is responsible for all chemical action. The interchange of electrons between

atoms accounts for what was once called "chemical affinity." How? In order to answer that question we must consider in a little more detail just what we mean when we say that one atom loses an electron or electrons to another. If we suppose that an electron is completely removed from the outer shell of one atom and drawn into the outer shell of another atom, these two atoms become oppositely charged. The one having lost an electron (a unit negative charge) now has an excess positive charge of one, since it was neutral to start with. The other, also being neutral to start with, now has an excess negative charge of one. It is easy to see that these two atoms will be attracted to each other, much as a fragment of paper is attracted to a fountain pen which has been rubbed upon a piece of woolen cloth. This mutual attraction of oppositely charged atoms, or "ions" as they may more properly be called, is one form of chemical combination. It is usually called "polar" union.

However, a great many chemical combinations cannot be explained upon this basis and it is necessary to construct a new postulate to account for the exceptions.

5. *Atoms can attain a stable configuration by sharing electrons with other atoms.* The outer shells of the atoms may be thought of in this case as intersecting or touching each other, so that the shared electrons may be thought of as belonging in common to the outer shells of two atoms at the same time. Each atom has an attraction for the shared electrons; neither has a sufficient excess of attraction over the other to pull the electrons entirely away from the other. Hence, by both holding to the shared electrons the two atoms are incidentally keeping together, just as two children struggling for the same toy are held together. This is what is commonly called "non-polar" union.[3]

Again it is necessary to introduce a new refinement. The chemists originally thought that the outside electrons might be considered as occupying positions which would coincide with the corners of a cube circumscribed about the nucleus of the atom. We find reasons to believe however that electrons in the outer shell have a tendency to pair off. This being the case, we find it better to consider electron pairs as occupying positions which would coincide with the corners of a regular tetrahedron circumscribed about the nucleus.

It is at first difficult to see how electrons could pair off—like electrical charges should repel each other. But it must be remembered that these electrons are almost certainly in motion and that electrons in motion set up

[3] In most cases it would be better to say "partially polar" union, for, although neither atom can pull the electrons entirely away from the other, one may be able to hold them somewhat closer to itself. This idea is the basis for a view particularly useful in organic chemistry. See Kharasch and Reinmuth, THIS JOURNAL, **5**, 404–18 (Apr., 1928).

magnetic fields. We make use of this fact in building electromagnets. We cause a stream of electrons to travel over a circular or spiral path by winding a coil of wire and sending a current through it. It is possible, therefore, that two electrons may travel in orbits such that the magnetic fields set up have a tendency to attract and neutralize each other.

This leads us to the idea that when atoms share electrons they must share pairs of electrons. It is quite possible that one of the electrons in a shared pair may have belonged originally to one atom, and that the other electron belonged originally to the other atom. At any rate we adopt as our hypothesis that the chemical "bond" in the "non-polar" or "partially polar" type of union consists of a pair of electrons shared by two atoms.

When two or more atoms are held together by the forces which we have been discussing they form units known as *molecules*. That definition is hardly necessary, but it may be well to add one or two more at this point. We have already spoken of that relatively small portion of the atom at the center, which contains all the protons and part of the electrons,[4] as the *nucleus*. We find it convenient to have some designation for the part of the atom which includes the nucleus and all the rest of the electrons except the outside layer—that part is called the *kernel*. The outside layer of electrons is called the *valence layer* or *valence shell*.

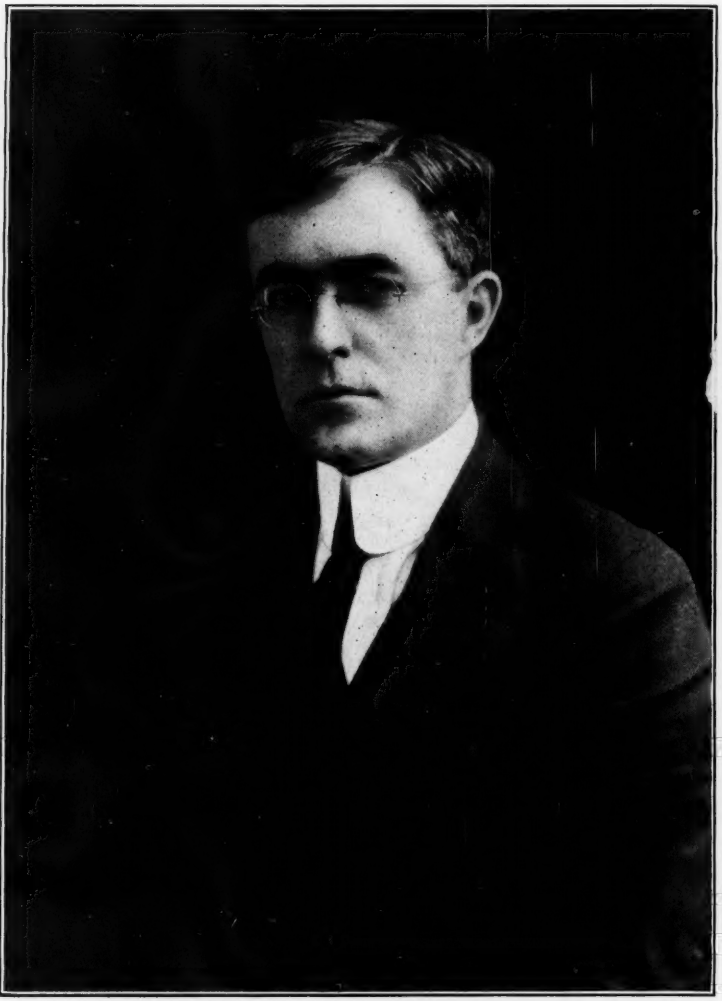
Application of the Theory in Explaining the Chemical Behavior of Hydrogen and Oxygen

We have now concocted a rather elaborate pudding; let us put it to the proof. Remembering that the hydrogen atom consists of one proton and one electron and also that our theory calls for two electrons in the first outside layer as a necessity for maximum stability, we would say at once that the hydrogen atom is unstable. We would not expect to find hydrogen in the atomic state under ordinary conditions. As a matter of fact we find that the hydrogen gas which we prepare in the laboratory is in the molecular form and that the molecules contain two atoms each.

Two hydrogen atoms, each with one valence electron, are able to pool their resources, so to speak, and share the pair of electrons, thus arriving mutually at a more stable configuration. So far our theory fits the facts.

We would also expect that hydrogen could share electrons with other atoms which have less than the quota necessary for maximum stability. Oxygen furnishes a good example. According to our theory the nucleus of the oxygen atom contains sixteen protons and eight electrons, the first layer of two electrons is complete, and the outside layer has six of the eight electrons necessary for maximum stability. Perhaps one oxygen atom could enter into a partnership with two hydrogen atoms whereby all would

[4] Except, of course, in the case of hydrogen, where the nucleus consists of one proton.



DR. IRVING LANGMUIR, ASSISTANT DIRECTOR OF THE RESEARCH LABORATORY OF THE GENERAL ELECTRIC COMPANY

Dr. Langmuir has been an important contributor to the modern theories of atomic structure, as applied to the explanation of chemical facts. His work has also led to the development of the improved modern electric light bulb, and the atomic hydrogen torch.

arrive at a more stable state. When we make an experimental test we find that under proper conditions oxygen and hydrogen do combine, and that they combine in the ratio of two of hydrogen to one of oxygen. Score another point for our theory.

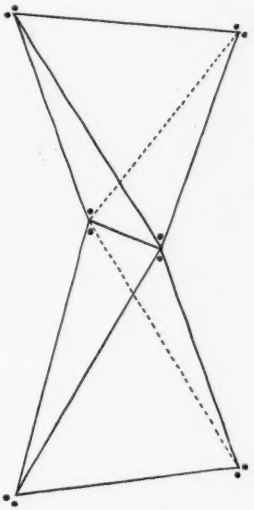


FIGURE 2

It next occurs to us that two oxygen atoms might be able to coöperate to attain greater stability. Experimentally, it is found that oxygen gas is indeed "diatomic." That is, its molecules contain two atoms each.

Recalling our statement that the partially polar bond consists of a pair of shared electrons we can use the following convenient schematic representation for the hydrogen molecule.

H : H

Here the two dots represent electrons and the H's represent the atomic kernels (in this case protons). We can use a similar schematic representation for the water molecule.

H :Ö: H

However, when we try to apply a similar scheme to the oxygen molecule we do not get quite so satisfactory a representation.

:Ö: :Ö:

Here it is more profitable to go to a little extra trouble and employ the tetrahedron idea which we have already mentioned. This is done in Figure 2. Only the valence shells of electrons are represented; the atomic kernels are omitted to avoid confusion.

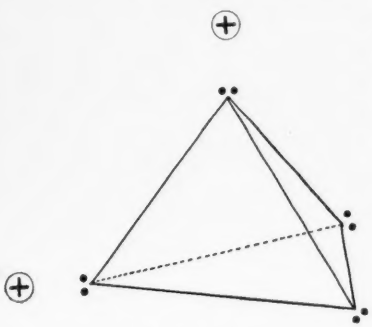
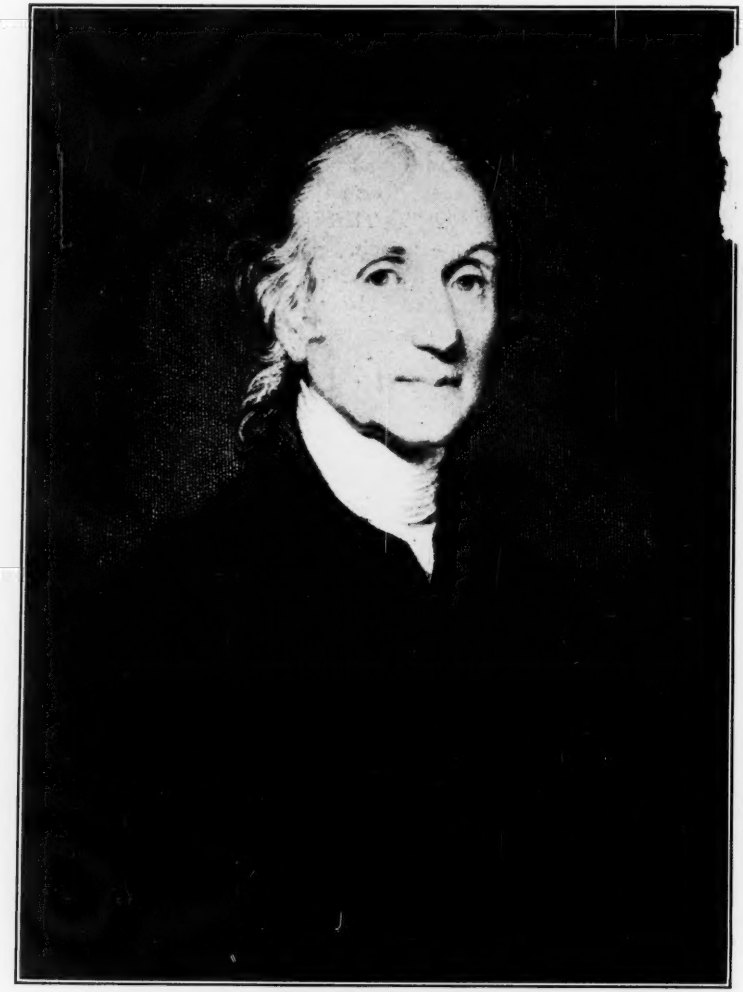


FIGURE 3

Even in the case of the water molecule we are able to better explain the properties of the compound by using the tetrahedral scheme, as in Figure 3. Here the kernel of the oxygen atom is again omitted, but the hydrogen kernels are represented by plus signs enclosed in circles. Figure 3 shows that the water molecule is not so symmetrical as our former plane representation would imply. This helps to explain why, when we combine two



JOSEPH PRIESTLEY, DISCOVERER OF OXYGEN

Priestley was not only a chemical investigator but a thinker and writer on educational, religious, and political subjects. Although he discovered oxygen and observed that it supported combustion, he defended the old phlogiston theory to the last. For an account of Priestley's life and work see the Priestley number of THIS JOURNAL, February, 1927.

gases like hydrogen and oxygen, we get a liquid. Molecules which are unsymmetrical are said to be "polar." This is a somewhat different use of the term polar from that which we employed in speaking of chemical bonds and should not be confused therewith. What is meant in this case is that, due to the unsymmetrical distribution of positive and negative charges, the molecule has an "electric moment." An electric moment is not the same thing as a magnetic moment but it produces a similar effect in one respect. The molecules tend to cling together or "associate." Naturally, "associated" compounds have a greater tendency to be liquid or solid at ordinary temperatures than unassociated compounds, other things being equal.

(*Applications will be continued in later issues. Students who desire to pursue the subject of atomic structure more thoroughly will find an excellent and lucid exposition in the series of five articles by Professor Maurice L. Huggins of Stanford University, California. These articles appeared in the October, November, and December, 1926, and the January and February, 1927, numbers of* THIS JOURNAL. *In the first article of the series Professor Huggins gives a list of references to books on the subject.*)

WATER AND ITS COMPONENTS

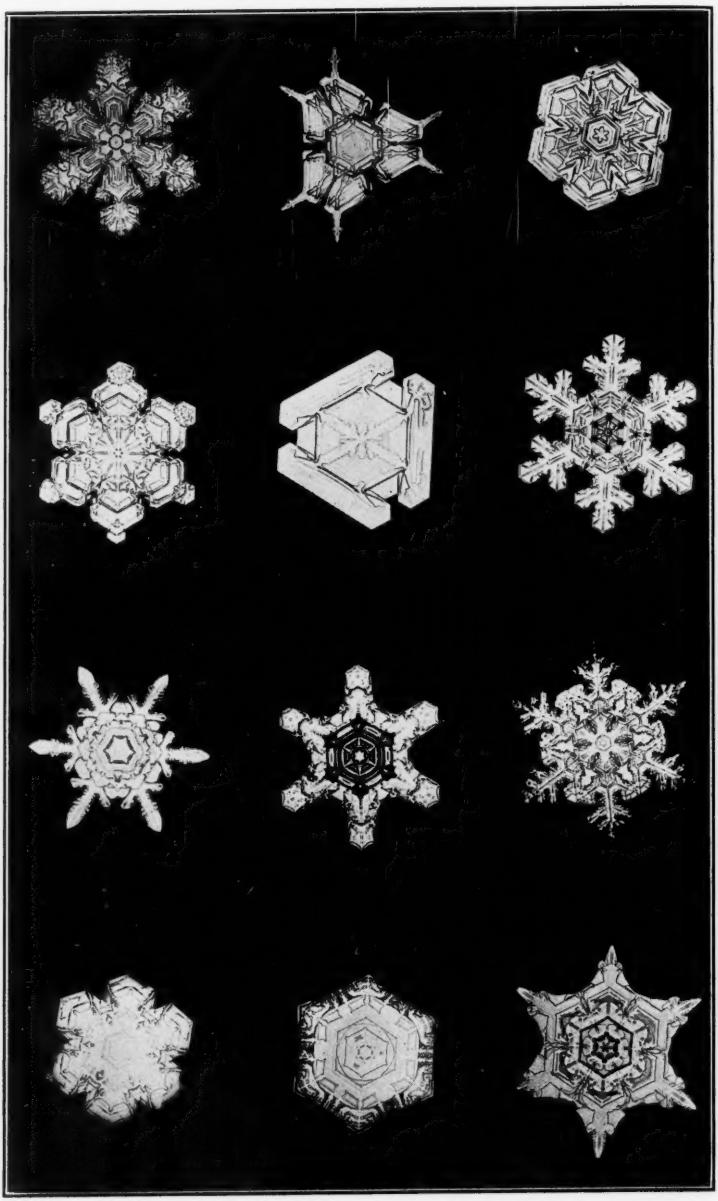
Water Crystals

The molecular configuration of a substance determines the form in which it crystallizes. In some substances these factors are greatly affected by temperature and pressure. Water is very sensitive in this respect and crystallizes in a number of different forms, depending upon the conditions prevailing at the time of crystallization. Of all the water crystals none are so interesting, so beautiful, and so infinite in variety as snowflakes. While most snow crystals have the same general "crystal habit" the extent of the variation in detail is almost inconceivable. Mr. W. A. Bentley[1] of Jericho, Vermont, has made a hobby of photographing such crystals through the microscope. He has found that, out of 4500 photographs taken, no two are alike, and he is inclined to believe that no two snowflakes are ever exactly alike. The pictures on the next page convey some idea of the loveliness and variety of these crystals.

Pressure and Freezing

We all realize that temperature has a great influence in determining whether a substance will assume the liquid or the solid state—whether it

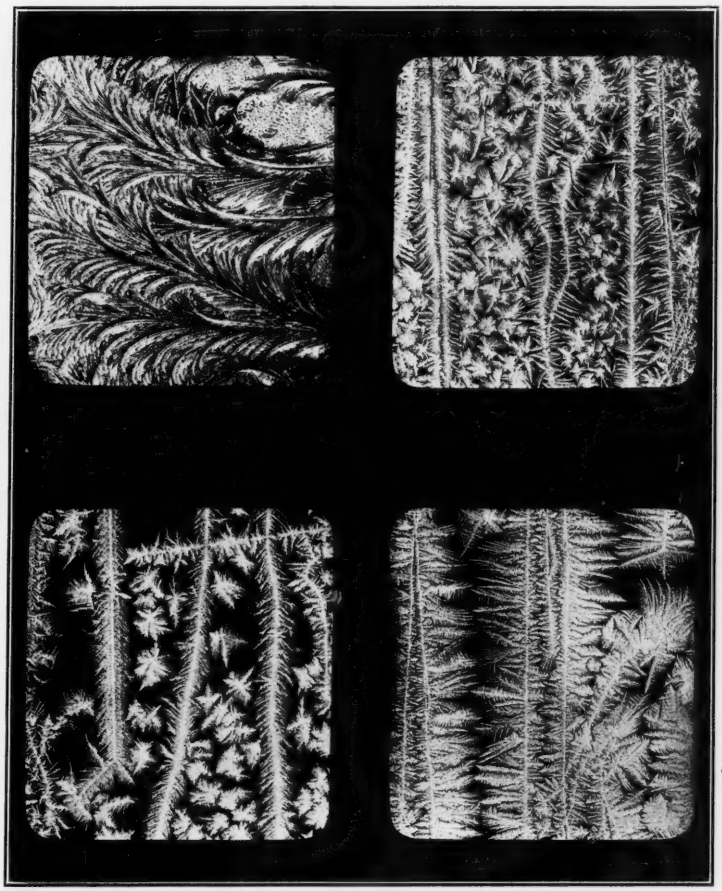
[1] An interview with Mr. Bentley and reproductions of some of his photographs appeared in the *American Magazine* for February, 1925. No doubt you can find the article at your public library if the subject interests you.



A Few Micro-Photographs of Snowflakes

will thaw or freeze, in other words. However, temperature is not all-important; pressure also plays a part.

Most substances are densest or most compressed in the solid state. Hence pressure, since it causes compression, encourages freezing. But



PHOTOGRAPHS OF FROST TRACERIES

water is an exception. It reaches its state of maximum density or compression at 4°C. and, as the temperature drops lower, begins to expand again. As it passes from the liquid to the solid state at 0°C. it expands still further.

As a consequence it is possible to melt ice merely by applying pressure, and without warming it at all. Everyone can think of instances in illustration of this peculiarity of water. On a cold morning one can often notice that his rubbers stick to an icy pavement. The weight of the body supplies sufficient pressure to melt a surface film of the ice. When the pressure is released, as in taking a step, the water promptly freezes again, thus freezing the rubber to the pavement. Snowballs are also made possible by this property of water. It is the pressure, rather than the heat, of the hands which causes the snow to melt. When the pressure is released freezing takes place again immediately.

A very simple experiment has been devised and is often used to demonstrate the effect of pressure upon ice. Two weights, attached to the ends of a piece of wire are suspended over a block of ice. The pressure thus applied causes the wire to melt the ice and cut into it. As the wire gradually sinks the water freezes above it, giving the appearance that the wire has been frozen into a block of ice. This experiment is not successful if the surrounding atmosphere is too warm.

Pressure and Boiling

Pressure alters the boiling point as well as the freezing point—the greater the pressure, the higher the boiling point. Thus water boils at a lower temperature on a mountain top (where the atmospheric pressure is less) than at sea level (where the atmospheric pressure is greater). Professor Swietoslawski of the Polytechnic School at Warsaw, Poland, has devised so accurate an apparatus for determining boiling points that it is capable of indicating the difference in atmospheric pressure caused by a change in altitude from the laboratory floor to the desk top.[2] Obviously, the sensitivity of this apparatus is greater than that of the ordinary mercury barometer. The Meteorological Observatory at Warsaw finds that such an arrangement constitutes a very reliable indicator of weather changes.

"Dry" Steam

When steam is mentioned we generally think of the cloud which issues from the cap of a boiling automobile radiator. This, however, is not really steam but a cloud of tiny, condensed water droplets. Real steam is a gas and just as invisible as air. It may be raised to very high temperatures. In his book, "Keeping Up with Science,"[3] Dr. Edwin. E. Slosson tells how Dr. Robert F. Griggs succeeded in kindling fire from steam.

Dr. Griggs led an exploration party sent by the National Geographic Society to the Valley of Ten Thousand Smokes in Alaska. This valley

[2] For Professor Swietoslawski's description of his apparatus see the April, 1928, number of THIS JOURNAL, p. 469.

[3] "Keeping Up with Science," Harcourt, Brace and Co., New York, **1924,** p. 222.

overlies an immense volcanic area and water which finds its way below the surface issues from vents and fumaroles as steam.

We will let Dr. Slosson tell the rest of the story.

> Dr. Griggs and his companions made use of this gigantic steam kettle as a cook-stove during their explorations of the valley, but they found some of the blow-holes were altogether too hot. They would corrode the cooking utensils although nothing was coming out of them in most cases but pure, dry steam. It occurred to Dr. Griggs to see if it were not possible to set fire to a stick of wood by putting it in the steam, which of course is nothing but pure water in a gaseous state.
>
> The end of a walking-stick was cut into a brush of shavings and thrust into a fumarole. It soon began to smoke and to char, indicating a temperature nearly if not quite that of red heat. But wood will not burn in steam. It needs oxygen for combustion, and so the smoking and charred stick was quickly pulled out into the air. It immediately burst into flame, since it had been heated to about the temperature of combustion and needed only oxygen to burn.

"Water, Water Everywhere"

Nearly all textbooks call attention to the almost universal occurrence of water and cite the high percentages of this compound contained in many of our foods and in our bodies themselves. Sometimes the omnipresence of water gives rise to difficulties—we find it very hard to get rid of absolutely all water. A number of compounds are used as drying agents because of their strong affinity for water—some react with it; some merely dissolve in it. Fused sodium hydroxide, concentrated sulfuric acid, phosphorous pentoxide, and calcium chloride are all good drying agents. When it becomes necessary to remove the last traces of water, however, some more effective means must be devised.

Dr. Langmuir of the General Electric Company encountered this difficulty when he sought to completely remove the traces of water which he found to be responsible for the blackening of electric light bulbs. The strange furnace which was finally constructed to solve the problem has been described in the May, 1927, number of THIS JOURNAL, page 604.

Commercial Production and Uses of Hydrogen and Oxygen

Oxygen is produced commercially by two distinct methods—the liquefaction and subsequent fractional distillation of air, and the electrolysis of water. When the entire cost of production must be charged to the oxygen itself, the former method is generally the most economical. When a good market can be found for hydrogen, the latter system has the advantage.

Most of the oxygen so produced is used in connection with other gases in the cutting and welding of metals. While hydrogen can be, and often is, used as the fuel gas for such work, it is not as satisfactory as acetylene for some purposes and it is less economical to transport. Hence, there has

never been sufficient demand for hydrogen to warrant producing any great quantity of oxygen by the electrolytic method.

However, Dr. Langmuir of the General Electric Company has recently discovered that molecular hydrogen can be split into atomic hydrogen electrically and that atomic hydrogen flames are the hottest which have yet been produced. Atomic hydrogen torches have been invented and new

WELDING WITH THE ATOMIC HYDROGEN ARC

uses are being found for them every day. It appears as though it might soon be economical to produce most of our oxygen electrolytically.

Hydrogen serves other purposes than that of a fuel gas. A good many years ago, Dr. Paul Sabatier found that certain vegetable oils could be hardened or thickened into vegetable "lards" by saturating them with hydrogen in the presence of a catalyst. Nowadays such vegetable fats are even more widely used for cooking in this country than is pork lard.

Harris & Ewing, Washington, D. C.
DR. PAUL SABATIER, WHO FIRST HYDROGENATED VEGETABLE OILS

It has been discovered also that hydrogen can be catalytically combined with nitrogen to form ammonia. We shall discuss this process more fully when we take up nitrogen.

THE A. C. S. PRIZE ESSAY CONTESTS

For the past five years the American Chemical Society has been able to carry on, through the generosity of Mr. and Mrs. Francis P. Garvan, its annual prize essay contests. The essays published elsewhere in this number are those which won first prizes in the high-school contest for 1927–28. Prize-winning essays in the College and University Freshmen Contest for the past year appeared in the July issue.

The essay contests are to be continued during the scholastic year, 1928–29. Awards are offered in three classes—high and secondary schools; normal schools and teachers' colleges; and university and college freshmen. In each class the six subjects selected are the same. In the high-school class, six twenty-dollar gold pieces (one for each topic) and six certificates of honorable mention are offered as first and second prizes, respectively, for the

best essays submitted from each State. The six national first-prize winners each receive four-year scholarships to Yale, Vassar, or other institutions, each scholarship providing tuition fees and five hundred dollars annually. Six prizes of $500, six prizes of $300, and six prizes of $200 will be awarded to the writers of the first, second, and third best essays, respectively, on each of the six subjects enumerated, both in the normal school and the college freshmen classes.

The rules for the high- and secondary-school contest follow:

1. Any student enrolled in any high or secondary school in the United States, who has not completed sufficient work to satisfy college entrance requirements, is eligible to enter the Contest. Students who will graduate at mid-year may enter. It is not necessary to be enrolled in any chemistry courses, or to have studied chemistry previously.

2. A contestant may submit only one essay.

3. Essay must not exceed 2500 words. This condition must be strictly observed.

4. Essay must be the original work of the contestant and must be confined to one of the following subjects.

   1. The Relation of Chemistry to Health and Disease.
   2. The Relation of Chemistry to the Enrichment of Life.
   3. The Relation of Chemistry to Agriculture or Forestry.
   4. The Relation of Chemistry to National Defense.
   5. The Relation of Chemistry to the Home.
   6. The Relation of Chemistry to the Development of an Industry or a Resource of the United States.

5. Essay must be typewritten, double-spaced, have wide margins and be on one side of paper $8\frac{1}{2}'' \times 11''$. If typewriting facilities are not available then legible handwritten essays should be substituted. Illegible essays will not be accepted. Essays must bear the name, home address, and the name and address of the school of the contestant. The sheets must be numbered consecutively and securely fastened together.

6. All direct quotations must be enclosed in quotation marks and due credit must be given to sources of reference. Lengthy quotations must not be included.

7. Exhibits or illustrations must not be made a part of or accompany an essay.

8. Duplicates of essays submitted in former contests will not be accepted.

9. Essays must be received at the office of the Chairman of the State Awards Committee on or before March 1, 1929. Essays may be submitted through school authorities or individually. In the latter case a statement from a school official or teacher regarding enrolment should accompany the essay.

10. By the act of entering an essay in the contest, the writer gives to the Committee on Prize Essays of the American Chemical Society full right to its permanent possession, publication rights, etc.

11. No high- or secondary-school student who has been awarded a Garvan National Scholarship Prize in connection with any of the American Chemical Society's former Prize Essay Contests will be eligible to participate in the 1928–29 contest.

Rules for the other two contests are substantially the same but differ in some details. Full particulars can be obtained by writing to:

THE SECRETARY, COMMITTEE ON PRIZE ESSAYS,
AMERICAN CHEMICAL SOCIETY,
85 BEAVER STREET, NEW YORK CITY

Advice to Prospective Contestants

Perhaps the first bit of advice which we would like to offer should be addressed to those who are not yet "prospective contestants." It is—enter the contest. It is obvious that not everyone who enters can receive a prize. Nevertheless, the number of the awards offered affords the individual an unusually good chance to win something. And even though you do not receive a prize you will find that you have no cause to consider the time spent as wasted. For you will no doubt encounter many interesting things in your preparatory reading and learn much which cannot be included in the ordinary course in general chemistry.

When you have decided to take part in the contest talk the matter over with your chemistry instructor. He should be able to offer you many helpful suggestions. Perhaps he has already planned to include the writing of such essays as a part of the course, or to give extra scholastic credit to those who desire to write. It may be that your English instructor will also accept your essay as a theme and aid you in improving its expression.

Your first definite step toward the preparation of an essay will be the selection of your subject. If you have a special interest in any of the topics prescribed, by all means select that one. If you have no preference in the beginning a little general reading may enable you to make a choice. Perhaps there is a chemical industry in or near your town about which you can obtain first-hand information not readily available to everyone. If so, you have an advantage which you should seize.

In determining your subject it is well to remember that the actual title of your essay need not be precisely the same as the topic listed by the committee, nor need you cover all phases of one of those general subjects. If you feel that you can better treat one special aspect of a subject you should do so rather than attempt to diffuse your efforts over too broad a field. You must make sure, however, that your title is logically classifiable under one of the general subjects listed. An example of the sort of subject selection which we have recommended is found in the essay of Miss Dorothy Baker* which won a first prize in the secondary school contest for 1926–27. Miss Baker's subject was "The Relation of Chemistry to the Enrichment of Life." The actual title which she selected was "Chemistry as an Instrument of General Education," and she discussed somewhat the same aspects of the matter as are considered in the article beginning on page 1148, entitled "Why Study Chemistry?"

Here we would like to say in passing that "The Relation of Chemistry to the Enrichment of Life" is a subject which offers the thoughtful student of more than average maturity of mind an exceptional opportunity. It is easy to catalog the contributions of chemistry to material civilization and

* See THIS JOURNAL, **4**, 1120–5 (September, 1927).

these have both a direct and an indirect bearing on the enrichment of life. It is more difficult to deal with the more intangible, or with what we may call the philosophical, side of the subject. But the competitor who can successfully do so is assured of producing an outstanding piece of work.

Following this article you will find a classified list of references for the use of prize essay contestants. It would be neither possible nor desirable to read all the books listed, but you will undoubtedly obtain from this bibliography many suggestions as to sources of information. Your high-school or college library or the public library in your town should contain many of these books.

A final word of caution may not be amiss. In the use of references, try to digest what you read, making notes of essential points only for the purpose of jogging your memory. When you begin to write lay aside the books to which you have referred and present what you have to say in your own words and in accordance with the outline which you desire to follow. In short, do not abstract the writings of others. Secure your facts; then plan and execute something of your own—a creation into which your own personality enters.

BIBLIOGRAPHY FOR PRIZE-ESSAY CONTESTANTS*

1. The Relation of Chemistry to Health and Disease

"Bacteriology." Stanley Thomas. McGraw-Hill Publishing Co., Inc., New York.

"Chemistry and Recent Progress in Medicine." Julius Stieglitz. Williams & Wilkins, Baltimore, Md.

"Chemistry in Medicine." Julius Stieglitz, Editor. The Chemical Foundation, Incorporated, New York.

"Chemistry of Food and Nutrition." Henry C. Sherman. The Macmillan Co., New York.

"Daedalus, or Science and the Future." J. B. S. Haldane. Cambridge University Press, E. P. Dutton & Co., New York.

"Four Thousand Years of Pharmacy." Chas. H. LaWall. J. B. Lippincott Co., Philadelphia.

"Future Independence and Progress of American Medicine in the Age of Chemistry." A Committee of American Scientists. The Chemical Foundation, Incorporated, New York.

"Life of Pasteur." R. Vallery-Radot. Doubleday, Doran & Co., Inc., New York.

"Medical Organic Chemistry." E. V. McCollum. The Macmillan Co., New York.

"Microbe Hunters." Paul de Kruif. Harcourt, Brace & Co., New York.

"Modern Science and People's Health." Benjamin C. Gruenberg. W. W. Norton & Co., Inc., New York.

"Nutrition: The Chemistry of Life." L. B. Mendel. Yale University Press, New Haven.

"Readings in Science." J. A. Lester. Houghton Mifflin & Co., Boston.

* Compiled for the 1928–29 High-School Students' Essay Contest booklet.

"Recent Advances in Biochemistry." John Pryde. P. Blakiston's Son & Co., Philadelphia.

"The Romance of the Holes in Bread." I. K. Russell. Chemical Publishing Co., Easton, Pa.

"The Story of Drugs." Henry C. Fuller. The Century Co., New York.

"Vitamins." H. C. Sherman and S. L. Smith. Chemical Catalog Co., New York.

2. The Relation of Chemistry to the Enrichment of Life

"Chats on Science." Edwin E. Slosson. The Century Co., New York.

"Chemical Discovery and Invention in the Twentieth Century." Sir William A. Tilden. E. P. Dutton & Co., New York.

"Chemistry Applied to Home and Community." Pauline G. Beery. J. B. Lippincott Co., Philadelphia.

"Chemistry and Civilization." Allerton S. Cushman. E. P. Dutton & Co., New York.

"Chemistry and Its Relation to Daily Life." Louis Kahlenberg and E. B. Hart. The Macmillan Co., New York.

"Chemistry in Modern Life." Svante Arrhenius. D. Van Nostrand Co., New York.

"Chemistry in the Service of Man." Alexander Findlay. Longmans, Green & Co., New York.

"Chemistry in the Twentieth Century." E. F. Armstrong. The Macmillan Co., New York.

"Chemistry in the World's Work." Harrison E. Howe. D. Van Nostrand Co., New York.

"Chemistry of Familiar Things." Samuel Schmucher Sadtler. J. B. Lippincott Co., Philadelphia.

"Creative Chemistry." Edwin E. Slosson. The Century Co., New York.

"Discovery, or the Spirit and Service of Science." Sir Richard Gregory. The Macmillan Co., New York.

"The Realities of Modern Science." John Mills. The Macmillan Co., New York.

"The Romance of Chemistry." William Foster. The Century Co., New York.

3. The Relation of Chemistry to Agriculture or Forestry

"Bacteria in Relation to Soil Fertility." J. E. and E. O. Greaves. D. Van Nostrand Co., New York.

"Chemistry in Agriculture." Joseph S. Chamberlain, Editor. The Chemical Foundation, Incorporated, New York.

"Chemistry of Agriculture." Charles W. Stoddart. Lea & Febeger, Philadelphia.

"The Chemistry of Cellulose and Wood." A. W. Schorger. McGraw-Hill Publishing Co., Inc., New York.

"Chemistry of the Farm and Home." Tottingham and Ince. Webb Publishing Co., St. Paul.

"Chemistry of Plant Life." Roscoe W. Thatcher. McGraw-Hill Publishing Co., Inc., New York.

"Chemistry of Plant and Animal Life." Harry Snyder. The Macmillan Co., New York.

"Chemistry of Wood." Hawley and Wise. Chemical Catalogue Co., Inc., New York.

"Fertilizers." E. Voorhees. The Macmillan Co., New York.

"Fertilizers, Their Sources, Manufacture and Uses." Herbert Cave. Isaac Pitman & Sons, New York.

"Forest Products." Nelson Brown. John Wiley & Sons, New York.

"Forest Products in the Chemical Industries." L. F. Hawley. U. S. Dept. of Agriculture, Forest Service, Washington, D. C.

"Insecticides and Fungicides." Anderson and Roth. Chapman, Hall & Co., London.

"Organic Agricultural Chemistry." Joseph S. Chamberlain. The Macmillan Co., New York.

"Plant Products and Chemical Fertilizers." S. H. Collins and G. Redington. D. Van Nostrand Co., New York.

"Readings in Science." J. A. Lester. Houghton Mifflin & Co., Boston.

"The School Book of Forestry." C. L. Pack. American Tree Assoc., Washington, D. C.

"Soil and Civilization." Milton Whitney. D. Van Nostrand Co., New York.

"Soil Characteristics." P. Emerson. McGraw-Hill Publishing Co., Inc., New York.

"Soil Conditions and Plant Growth." E. J. Russell. Longmans, Green & Co., New York.

"Soil Fertility and Permanent Agriculture." C. G. Hopkins. Ginn & Co., Boston.

"Story of the Soil, from the Basis of Absolute Science and Real Life." C. G. Hopkins. Richard G. Badger, Boston.

"Vocational Chemistry." John J. Willaman. J. B. Lippincott Co., Philadelphia.

4. The Relation of Chemistry to National Defense

"Callinicus: A Defense of Chemical Warfare." J. B. S. Haldane. E. P. Dutton & Co., New York.

"Chemical Warfare." A. A. Fries and C. J. West. McGraw-Hill Publishing Co., Inc., New York.

"Chemistry in the World's Work." Harrison E. Howe. D. Van Nostrand Co., New York.

"Medical Aspects of Chemical Warfare." Edward B. Vedder. Williams & Wilkins Co., Baltimore.

"The Riddle of the Rhine." Victor Lefebure. The Chemical Foundation, Incorporated, New York.

5. The Relation of Chemistry to the Home

"Applied Chemistry." Ira D. Garard. The Macmillan Co., New York.

"Chemistry and the Home." H. E. Howe and F. M. Turner, Jr. Charles Scribner's Sons, New York.

"Chemistry Applied to Home and Community." Pauline G. Beery. J. B. Lippincott Co., Philadelphia.

"Chemistry of the Farm and Home." Tottingham and Ince. Webb Publishing Co., St. Paul.

"Elementary Household Chemistry." J. F. Snell. The Macmillan Co., New York.

"Feeding the Family." Mary S. Rose. The Macmillan Co., New York.

"Food Products." Henry C. Sherman. The Macmillan Co., New York.

"Food Study." Mabel Wellman. Little, Brown & Co., Boston.

"Science of Home and Community." Gilbert H. Trafton. The Macmillan Co., New York.

"Scientific Preservation of Food." Thomas M. Rector. John Wiley & Sons, Inc., New York.

"Source, Chemistry and Use of Food Products." E. H. S. Bailey. P. Blakiston's Son & Co., Philadelphia.

6. The Relation of Chemistry to the Development of an Industry or a Resource of the United States

"Applied X-Rays." George L. Clark. McGraw-Hill Publishing Co., Inc., New York.

"Chemical Discovery and Invention in the Twentieth Century." Sir William A. Tilden. E. P. Dutton & Co., New York.

"Chemistry in Industry." Vol. I. Harrison E. Howe. The Chemical Foundation, Incorporated, New York.

"Chemistry in Industry." Vol. II. Harrison E. Howe. The Chemical Foundation, Incorporated, New York.

"Chemistry of Commerce." Robert Kennedy Duncan. Harper & Brothers, New York.

"Gasoline—What Everyone Should Know About It." T. A. Boyd. Frederick A. Stokes Co., New York.

"Industrial Chemistry." Allen Rogers. D. Van Nostrand Co., New York.

"Industrial Chemistry." Henry K. Benson. The Macmillan Co., New York.

"Metallurgy and Its Influence on Modern Progress." Sir Robert A. Hadfield. D. Van Nostrand Co., New York.

"Municipal Chemistry." Charles Baskerville. McGraw-Hill Publishing Co., Inc., New York.

"Popular Research Narratives." Engineering Foundation. Williams & Wilkins, Baltimore, Md.

"Potash." J. W. Turrentine. John Wiley & Sons, Inc., New York.

"Profitable Science in Industry." Farnham, Hall, King and Howe. The Macmillan Co., New York.

"The Story of Copper." Watson Davis. The Century Co., New York.

"The Story of Sugar." C. F. Bardorf. Chemical Publishing Co., Easton, Pa.

"Survey of American Chemistry." Vols. I and II. W. J. Hale and C. J. West. Chemical Catalog Co., New York.

"Synthetic Organic Compounds." C. P. Schotz. Ernest Benn, Ltd., London.

"What Price Progress." Hugh Farrell. G. P. Putnam's Sons, New York.

7. Biography and History[1]

"Chemistry in America." Edgar F. Smith. Appleton & Company, New York.

"Chemistry in Old Philadelphia." Edgar F. Smith. J. B. Lippincott Co., Philadelphia.

"Chemistry to the Time of Dalton." E. J. Holmyard. Oxford University Press, New York.

"Concise History of Chemistry." T. P. Hilditch. D. Van Nostrand Co., New York.

"Eminent American Chemists." (Portraits and Sketches.) D. H. Killefer, Editor. D. H. Killefer, New York.

"Eminent Chemists of Our Time." Benjamin Harrow. D. Van Nostrand Co., New York.

"Essays in Historical Chemistry." T. E. Thorpe. The Macmillan Co., London.

"Famous Chemists." E. Roberts. The Macmillan Co., New York.

"Famous Chemists: The Men and Their Work." Sir William A. Tilden. E. P. Dutton & Co., New York.

---

[1] This and succeeding lists include helpful books besides some of those already given under the special divisions of the topics for essays.

"Historical Introduction to Chemistry." T. M. Lowry. The Macmillan Co., New York.

"History of Chemistry." Forris-Jewett Moore. McGraw-Hill Publishing Co., Inc., New York.

"History of Chemistry." Sir Thomas Edward Thorpe. G. P. Putnam's Sons, New York.

"Life of Pasteur." R. Vallery-Radot. Doubleday, Doran & Co., Inc., New York.

"Pierre Curie." Madame Curie. Trans. by C. and Vernon Kellogg. The Macmillan Co., New York.

"Pioneers of Progress: Men of Science. Faraday, Priestley, Dalton and Others." The Macmillan Co., New York.

"Short History of Chemistry." F. P. Venable. D. C. Heath & Co., New York.

"Stories of Scientific Discovery." Mrs. D. B. Hammond. Cambridge University Press, Cambridge.

"Story of Early Chemistry." John M. Stillman. D. Appleton & Co., New York.

8. General Chemistry

"American Chemistry." Harrison Hale. D. Van Nostrand Co., New York.

"Chemical Discovery and Invention in the 20th Century." Sir William A. Tilden. E. P. Dutton & Co., New York.

"Chemical History of a Candle." Michael Faraday. Harper & Brothers, New York.

"Chemistry and Civilization." Allerton S. Cushman. E. P. Dutton & Co., New York.

"Chemistry and Its Relation to Daily Life." Louis Kahlenberg and E. B. Hart. The Macmillan Co., New York.

"Chemistry in Modern Life." Svante Arrhenius. D. Van Nostrand Co., New York.

"Chemistry in the Service of Man." Alexander Findlay. Longmans, Green & Co., London, New York.

"Chemistry in the Twentieth Century." E. F. Armstrong. The Macmillan Co., New York.

"Chemistry in the World's Work." Harrison E. Howe. D. Van Nostrand Co., New York.

"Chemistry of Familiar Things." Samuel S. Sadtler. J. B. Lippincott Co., Philadelphia.

"Creative Chemistry." Edwin E. Slosson. The Century Co., New York.

"Discovery, or the Spirit and Service of Science." Sir Richard Gregory. The Macmillan Co., New York.

"Everyman's Chemistry." Ellwood Hendrick. Harper & Brothers, New York.

"Introduction to Organic Research." E. Emmet Reid. D. Van Nostrand Co., New York.

"Modern Chemistry." Sir William Ramsay. E. P. Dutton & Co., New York.

"Modern Chemistry and Its Wonders." Geoffrey Martin. Sampson, Low, Marston & Co., Ltd., London.

"The Romance of Chemistry." William Foster. The Century Co., New York.

"Sermons of a Chemist." Edwin E. Slosson. Harcourt, Brace & Co., New York.

"The Story of Chemistry." Floyd Darrow. The Bobbs-Merrill Co., Indianapolis, Ind.

"Triumphs and Wonders of Modern Chemistry." Geoffrey Martin. D. Van Nostrand Co., New York.

"Wonder Book of Chemistry." Jean H. C. Fabre. The Century Co., New York.

9. General Science

"The A B C of Atoms." Bertrand Russell. E. P. Dutton & Co., New York.

"Artificial Light: Its Influence on Civilization." M. Luckiesh. The Century Co., New York.

"Cambridge Readings in the Literature of Science." W. C. D. and M. D. Whetham. The Macmillan Co., New York.

"Chats on Science." Edwin E. Slosson. The Century Co., New York.

"Chemistry of To-Day." P. G. Bull. J. B. Lippincott Co., Philadelphia, Pa.

"Concerning the Nature of Things." Sir William Bragg. Harper & Brothers, New York.

"Creative Knowledge." Sir William Bragg. Harper & Brothers, New York.

"Foundations of the Universe." M. Luckiesh. D. Van Nostrand Co., New York.

"Here and There in Popular Science." Jean H. C. Fabre. The Century Co., New York.

"Icarus, or the Future of Science." Bertrand Russell. E. P. Dutton & Co., New York.

"Keeping Up with Science." Edwin E. Slosson. Harcourt Brace & Co., New York.

"The New Stone Age." Harrison E. Howe. The Century Co., New York.

"A Popular History of American Invention." Vols. I and II. Waldemar Kaempffert. Chas. Scribner's Sons, New York.

"Popular Research Narratives." Vol. I. Engineering Foundation. Williams & Wilkins Co., Baltimore.

"Popular Research Narratives." Vol. II. Engineering Foundation. Williams & Wilkins Co., Baltimore.

"Popular Science Lectures." Vol. I. The Philadelphia College of Pharmacy & Science, Philadelphia.

"The Recent Development of Physical Science." William Whetham. P. Blakiston's Son & Co., Philadelphia.

"The Romance of the Atom." Benjamin Harrow. Boni & Liveright, New York.

"Science and Life." Gilbert H. Trafton. The Macmillan Co., New York.

"Science and Life." Frederick Soddy. E. P. Dutton & Co., New York.

"Science and the Modern World." Alfred North Whithead. The Macmillan Co., New York.

"Science and the Nation." A. C. Seward. Cambridge University Press, Cambridge.

"The Science of Common Things." S. F. Tower and J. R. Lund. D. C. Heath & Co., New York.

"Science Remaking the World." O. W. Caldwell and E. E. Slosson. Doubleday, Doran & Co., Inc., New York.

"Scientific Research and Human Welfare." Franklin Harris. The Macmillan Co., New York.

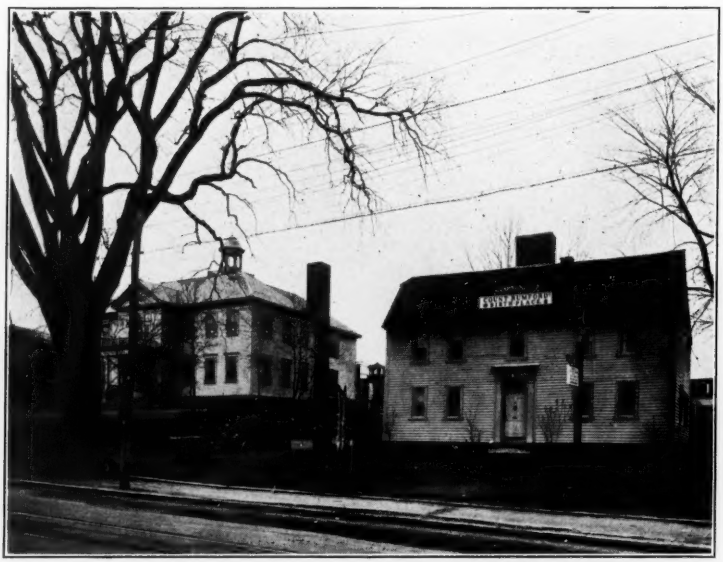
"Stories of Scientific Discovery." Mrs. D. B. Hammond. Cambridge University Press, Cambridge, Eng.

STUDENT CONTRIBUTIONS

Is your chemistry club carrying on some worthwhile project? Have you, yourself, an interesting chemical hobby? Have you devised an original chemical toy or demonstration apparatus? Have you built a working model of a chemical plant or a piece of chemical machinery? Have you a chemical collection of any kind?

Tell us and other students about it in an article of about one thousand words. If possible, illustrate your article with drawings or photographs, or both. In preparing your manuscript, observe the directions to authors set forth on page 1036.

$10.00 will be awarded the student contributing the best item received on or before October 15, 1928. $5.00 will be paid for any other articles accepted for publication. Address your contribution to the Associate Editor, JOURNAL OF CHEMICAL EDUCATION, the Johns Hopkins University, Baltimore, Md.



George E. Lawrence Co., Boston, Mass.

THE BIRTHPLACE OF BENJAMIN THOMPSON, COUNT RUMFORD, WHOSE PORTRAIT APPEARS AS THE FRONTISPIECE OF THIS ISSUE

This building still stands at North Woburn, Massachusetts, and is maintained as the museum of the Rumford Historical Society.

Chemical Digest

PHOTOGRAPHY

In turning to the history of photography[1] we find that it was less than a century ago, 1839 to be exact, that the Frenchman, Daguerre, an opera scene painter by trade, publicly announced the daguerreotype process, which marked the beginning of practical photography. It is interesting to note that the discovery which led up to this announcement was merely accidental. Daguerre discarded some of his plates covered with iodide of silver because they had been exposed too short a time. It so happened that they were placed in a cupboard containing some chemicals. Sometime later he was surprised to find pictures upon these same plates. After a systematic study of the effect produced, he found, by eliminating the chemicals one after another, that a dish of mercury was responsible. Further study along this line culminated in the announcement mentioned above.

The story of modern photography and "a few of the ways by which the camera, whose highest aim was once to take a picture of somebody's relative, has become a priceless servant of industry and science" are interestingly related by Ellsworth Bennett in a recent issue of *Popular Science Monthly*.[2] Quoting from this article:

> Many the lawsuit that has been decided by a photograph, such is the reputation of the modern camera as an eye that sees every detail and does not forget. But today's camera can do more than that. Science and industry alike know it as an ally. It can photograph things that no human eye can ever see. It can picture lightning, study the explosion of blasting powder, slow up for human eyes the crash of an airplane into a concrete wall. So fast are cameras that they can capture an event that is over long before you realized it was going to happen. So sharp is the camera's eye that it can peer through solid metal.
>
> Today any one can buy a camera that will take a photograph in the incredibly brief time of a thousandth of a second and "freeze" into stark immobility racing automobiles and leaping athletes. Specially built cameras perform wonders greater than these, and catch the jagged, twisting forks of a streak of lightning—the speeding flight of a rifle bullet—or the flying droplets of a splash of water stopped in mid-air.
>
> All these are things that science would like to know more about, and is studying with the aid of the camera.

Several unique cameras and their application to the solving of various scientific problems are called to the attention of the reader. On reading further, we find:

[1] "The Chemistry of Photography. I. Historical Considerations," S. E. Sheppard, THIS JOURNAL, **4,** 298–312 (March, 1927).

[2] E. Bennett, "New Magic Worked by Cameras," **113,** 25–6, 138–9 (Sept., 1928).

Not only can the camera photograph things you might see if they happened slowly or fast enough—but it can picture things you could never see because your eyes aren't built for it! Things like x-rays—like ultra-violet rays, or "black light," a component of sunlight—and like infra-red, or invisible heat, radiations simply fail to register on the human optical apparatus. But the camera catches them. We are forever blind to anything "redder" than red, or "more violet" than violet, the two colors that are the extremes of our visual span; but there the camera is just commencing.

That is why the camera is so valuable in any kind of chemical or astronomical analysis in which the spectroscope, a device to split light into its whole range of visible and invisible colors, is used—an analysis, for instance, such as that which resulted in the discovery by two University of Illinois chemists of the new chemical element illinium, not long ago, through the photographic evidence of hitherto unseen lines in the x-ray spectrum, or light-band, of a mineral used in the manufacture of gas mantles.

. . . . . And the value of x-ray photographs needs no comment. They reveal everything from hidden flaws in metal to the innermost constitution of the human organism. In medicine and surgery they are immediate means to diagnosis and cure. They detect forgeries, alterations of checks, and counterfeit money.

Infra-red rays—invisible light waves beyond the red rays you can see—have the peculiar power of penetrating fog and haze; and airplane photographs made exclusively by this peculiar light, with cameras and films capable of using it, show a startling clearness obtained in no other way.

. . . . . Most important of all photography's uses, however, is its ability to see more accurately than the human eye—and to preserve an indelible record of what it sees. That is why every industry and every science, as well as many a law court, calls upon the camera for its unfailing record. Go to any great corporation, any factory or industrial concern, and you will find drawer upon drawer of photographs that have recorded for all time everything from the building of a dam to the forging of a bolt. And science esteems the camera as highly as industry.

The recent announcement of natural color motion pictures for the amateur marks another important event in the history of photography. For the story of the pioneer work leading toward motion pictures in color we are indebted to *Science Service*.

The close and lasting connection of the two famous American inventors, George Eastman and Thomas Edison, began nearly forty years ago for it was in August, 1889, that Eastman sent to Edison the first samples of the flexible photographic film that solved the problem of the motion-picture.

Edison himself got the germ of his idea from a toy of his childhood, the Zoetrope, in which a rotating paper panorama gave a fleeting illusion of motion to those who peeked through the slits of the drum. Edison first tried to produce motion pictures by means of microscopic photographs arranged spirally on a circular glass plate like a phonograph disk record, but such a series was too small and short and he did not get far until the Eastman Kodak Company at Rochester had succeeded in sensitizing the gelatine coating of a strip of cellulose nitrate in unlimited length. With this film Edison equipped his peep-show kinetoscope which promptly became popular.

Toward the end of the last century Edison attempted to improve the motion-pictures by producing them in natural colors. In 1896 he tried hand-painted films. Others were also working on the same problem.

But nothing spectacular appeared in this field until 1910 when Charles Urban showed his kinemacolor at Brighton, England. This was a two-color process, red and

green being taken and projected alternately by means of a rotating disk of tinted filters. Because an image on the retina persists for about a sixteenth of a second before it fades away, each color fused with the succeeding one, except when movement was too fast. But when a horse was running the legs showed alternately a glaring red and green which somewhat impaired the illusion. The most popular of the kinemacolor films was the ceremonies of the Durbar at Delhi, India, in 1912.

The Gaumont process was more scientific but also more complicated for it employed three pictures taken in the three primary colors by three lenses on the same film and projected through three objectives. For still pictures taken on glass plates it has been found possible to get satisfactory color effects by the use of ruled lines or dots or scattered starch grains in two or three colors but these are apt to show their pattern when enlarged to the size of the theater screen.

The more recent inventions, the Prizma, Technicolor, and Kodachrome processes, also use two complementary colors, but on the opposite sides of the same double-coated strip. Each side represents the scene as photographed through a tinted filter of its own color and the white light shining through the two colored films takes the hue and design of both and throws the combination on the screen. The two colors are so selected as to cover singly or in varying proportions all the tints and shades of the original scene as nearly as any two colors can. A red inclined to orange and a green inclined to blue are the couple generally chosen.

But all processes depending upon dyes are more or less defective. The ideal method would be to employ the principle of the prism which converts white light into a band of pure colors and can as readily recombine them. The advantages of this were first pointed out in 1869 by a Frenchman, Charles Cros, who said:

"The synthesis by refraction gives one of the most elegant solutions of the problem . . . . . Thus one will have the reproduction of a natural object either direct in the eye or on a screen. This solution is remarkable in that the result does not depend on an artificially colored product. The colors are thus transformed under purely geometrical conditions and these conditions regenerate in turn the colors. The apparatus only renders in this way that which it receives."

Dozens of inventors have tried to apply the principle of the prism to color photography since it was first suggested nearly seventy years ago. Among the devices employed were shifting prisms, diffraction gratings or slits, micro-spectroscopes, pinhole screens, multiple lenses and corrugated filters or films.

The recent achievement of the Eastman Kodak Company is in finding a way of adapting the principle of the prism, discovered by Sir Isaac Newton, to the hand camera so that the amateur can make his own motion-pictures in the natural colors of the scene he snaps.

The demonstration of the amateur natural color movies held on July 30th at the home of George Eastman, photographic pioneer and head of the Eastman Kodak Company, was attended, according to *Science Service*, by the following group of inventors, scientists, and public men:

Thomas A. Edison, whose motion-pictures have now been made colorful; Frederick E. Ives, inventor of the half-tone process, the fundamental principle of which is used in the new color movies; his son, Dr. H. E. Ives of Bell Telephone Laboratories, who steered the development of telephoned photographs and television demonstrated within the last two years; Mr. Leo H. Baekeland, inventor of Velox photographic paper, as well as the synthetic resin bakelite; Dr. E. F. W. Alexanderson, television inventor; Dr. W. D. Coolidge, inventor of x-ray and cathode-ray tubes that bear his name; Dr. Michael I. Pupin, the physicist who made long distance telephone possible; Hiram

Percy Maxim, inventor; Dr. G. K. Burgess, director of the U. S. Bureau of Standards; Sir James Irvine, Scottish chemist; Dr. Henry Fairfield Osborn of the American Museum of Natural History; Gen. John J. Pershing; Owen D. Young, General Electric Company head; Maj.-Gen. James G. Harbord, president of the Radio Corporation; Dr. John J. Tigert, U. S. Commissioner of Education; Frank David Boynton, Ithaca superintendent of schools; Karl A. Bickel, president of the United Press Associations; Kent Cooper, general manager of the Associated Press; Roy Howard of the Scripps-Howard Newspapers; Adolph S. Och, publisher of the *New York Times;* David Lawrence, publisher of the *U. S. Daily;* and Dr. Edwin E. Slosson, director of *Science Service.*

For a concise but understandable account of the announced three-color process used in reproducing pictures in their natural colors on the screen, we refer you to the *Industrial Bulletin*[3] of Arthur D. Little, Inc.

The three-color method is capable of faithfully reproducing all the colors of the spectrum, whereas by the other two-color dyed film methods some colors are absent, or at best imperfectly reproduced. A three-color process has been the goal of all workers in this field, but until the present no satisfactory solution had been found.

The new process utilizes a transparent, striped filter attached to the camera lens, colored red, green, and blue, each colored strip transmitting a light ray of its own kind. For example, a purple aster in the garden being photographed reflects light that may be considered a mixture of red and blue. The red stripe in the filter permits an amount of red light proportional to the red component of the aster to pass, and the blue filter passes the blue component. Thus all the light impinging on the filter is broken up into the three colors and in varying intensity, depending on the quality and quantity of light reflected from the object photographed. After passing through the colored filter the light is focussed on a special film, embossed with a series of minute cylindrical lenses running the entire length of the film, with the light sensitive emulsion on the reverse side. There are five hundred and fifty-nine of these lenses or ridges to an inch of width. These lenses, which are a part of the film itself, act like prisms, bending each of the three colors of light rays from the filter through slightly different angles, thus focussing them upon the emulsion in adjacent position according to color.

The light thus falling on the emulsion causes a chemical reaction to take place as in ordinary photography. Due to a special treatment the film receives after exposure, it is actually a positive. It looks not unlike the ordinary black and white picture film, and is without coloration.

This film, after being put through the reversal process, has a series of opaque and transparent points corresponding to the red, green, and blue lights that have passed through the filter. If the whole procedure for taking the picture is reversed and the light is passed by means of a projector through the film, lenses and a filter identical with the one used in taking the picture, a large number of minute red, green, and blue points are projected on the screen. With these three colors in varying proportion and intensity it is possible to reproduce faithfully the scene photographed in all the colors and shades registered by the eye.

Although this new process appears to be far superior in simplicity and accurate reproduction to anything previously available in the colored-film field, several important limitations are noted.

As yet copies of the original film are difficult to make and the method at present is therefore of greater interest to the amateur than to the movie magnate or the movie fan.

[3] *Ind. Bull.*, Arthur D. Little, Inc., No. 20, Aug., **1928.**

Photographic prints in natural colors are still the hobby of the highly skilled specialist, but their commercial application is limited to the preparation of advertising illustrations and a few other purposes that warrant the appreciable expense now involved. With a simple and practical colored film available we may soon see the colored movie and the colored print produced at a cost comparable with the black and white approximation with which we must now be contented.

M. W. G.

Experimental College Completes First Year. The unique experimental college at the University of Wisconsin, which is being closely watched by educators, has completed its first year, and the results are promising, according to Prof. Alexander Meiklejohn, its chairman.

Prof. Meiklejohn, who spoke at the University of Chicago, said that the 120 freshmen who set out to spend an entire college year studying the golden age of Athenian civilization were bewildered at the start by the amount of freedom given them and the degree of self-reliance they were expected to display. Most of the students, however, finished the year with enthusiasm and a real capacity for work. Only nine of the freshmen dropped out.

No conclusion as to the success of the experiment can be drawn until the second year of the course is completed, Prof. Meiklejohn emphasized. It is understood that the sophomore course will focus upon the development of modern civilization in some country of Europe or America. Just as the Greek course was limited to the fifth century B.C., so the modern study would be limited to the past century.

The experimental college has no classroom work and no lectures. The freshmen who elected the course lived in a separate dormitory with the 11 teachers of their faculty. The professors were not chosen for special training in classical lines, and they have done approximately the same reading as their students.—*Science Service*

Chicken Tumor May Be Caused by Enzyme. A further step toward the eradication of cancer may result from recent experiments at the Rockefeller Institute for Medical Research by Dr. James B. Murphy, O. M. Helmer, and Ernest Sturm. These investigators have reported to the technical magazine, *Science*, that the substance that causes chicken tumors is very like the enzymes, which in yeast, for instance, decompose sugar in alcoholic fermentation, and in certain juices of the stomach and intestines cause digestion of food.

Chicken tumors, or sarcomas, are not the same as human cancer, but they are enough alike to be good material for experimentation. If scientists can find the exact nature of the substances that cause cancer, they may soon find the cure for this disease. Enzymes are known to be substances which, without undergoing change themselves, cause changes in the structure and nature of other substances. This enzyme-like nature of the cancer principle probably speeds up the action by which the cells undergo the change from a normal body cell to a cancerous one.

In the experiments just reported, the investigators were able to treat proteins obtained from chicken tumors so that two parts, one a precipitate of material like mucus, and the other a fluid, resulted. The precipitate was found to be the agent that caused tumors when injected into chickens. This precipitate is composed of proteins, although not the same form of proteins contained in many foods.—*Science Service*

ABSTRACTS

TEACHING METHODS, AIDS, APPARATUS, AND SUGGESTIONS

A Buret Cleaner. F. H. FISH. *Science*, **67**, 654 (June 29, 1928).—A buret which resists the usual cleaning agents may often be cleaned by rinsing with 95% alcohol, draining, adding about 2 cc. alcohol and then 5 cc. conc. HNO_3, in the hood, and covering the top of the buret with a large test tube. After the action has subsided the buret may be easily washed clean. G. H. W.

An Automatic Mercury Cleaner. F. J. DENT. *Chem. & Ind.*, **47**, 618 (June 15, 1928).—An apparatus, designed for the continuous and automatic washing of mercury with dilute nitric acid, is described with the aid of a diagram. An air pump is used to lift the mercury to the top of the tube containing the acid. E. R. W.

A Beaker Rack for Decantation. A. H. MOODY. *Chem.-Analyst*, **17**, 19 (Jan., 1928).—This rack was designed to hold the beaker in such a position as to decrease the disturbing of the precipitate produced by the motion of the liquid during decantation. Full directions for construction are given. M. W. G.

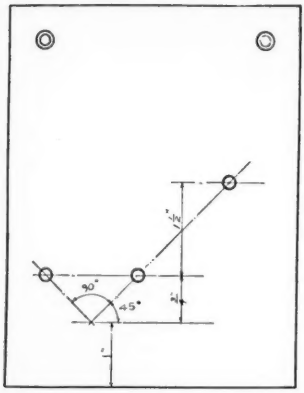


FIGURE 1

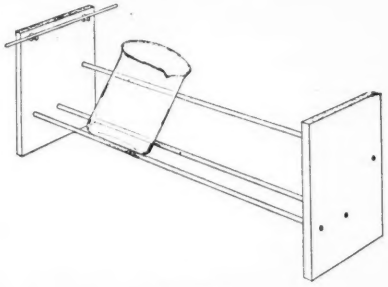


FIGURE 2

A Cork and Stopper Board. M. G. MCHENRY. *Chem.-Analyst*, **17**, 18 (Jan., 1928).—This is a means of saving the time of the student and the storekeeper in the fitting of rubber stoppers and corks. A board ten inches by twenty-four inches is large enough to hold all the sizes of both corks and stoppers commonly used. Each one is fastened on with a large headed nail, clinched into the board to prevent loss of cork or stopper, and is mounted small end outward. There is sufficient room to put the number and price of each sample, as well as to put further directions or information. The student brings his flask, etc., to the board, finds by trial the size needed, thus losing no time when he applies at the storeroom window. M. W. G.

Files as Glass Knives. GEORGE A. HUNT. *Chem.-Analyst*, **17**, 17 (Jan., 1928).—In a laboratory where there is much glass manipulation, it is quite essential to have an efficient instrument for scratching glassware preliminary to breaking. The triangular file, which is traditional in many laboratories, works quite well for a time, but eventually becomes dull and a source of much exasperation when one tries to find a few remaining spots which will still bite into the glass.

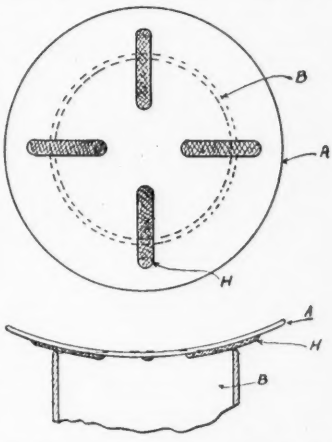
A very efficient glass knife may be made from this "useless" file by the use of an ordinary emery or carborundum wheel by grinding the edges of the file on each side until they are sharp—using care not to grind so fast as to draw the temper of the metal.

A still better knife can be made by grinding smooth the two small sides of a flat file. This leaves the four corners smooth on one side but jagged on the other. When these edges become dull it is only necessary to take a little more of the smooth sides off on the wheel and the edges are as good as new. M. W. G.

Cover Supports for Beakers and Dishes. H. SPURRIER. *Chem.-Analyst*, **17**, 17–8 (Apr., 1928).—Complete details, with diagrams, are given for making these desirable and useful cover supports. Many advantages attend the use of this support, some of which are as follows: (1) the cover tends to remain central and does not wabble, (2) there is only one piece to handle, (3) scraps of rod $1^1/_2$ inches long may be used up,

(4) the tripods may conveniently be stored one leg down in a tumbler beside the stirring rods. M. W. G.

A New Watch Glass. C. E. IRION. *Chem.-Analyst*, **17**, 18, 20 (July, 1928).—The new watch glass shown in the figure has been found very convenient in replacing the old style one. The shaded areas represent indentations in the surface of the watch glass and project out from the lower surface, thus acting as supporting surfaces. Directions for making this piece of apparatus are given. Some advantages claimed are: (1) ridges increase exposed surface by several per cent and hence greater and more rapid evaporation obtained, (2) ridges help direct wash water so that it will run off watch glass in desired place, (3) stability greater than older types, (4) center of glass is free so as to enable it to be bored for electrolytic work and also for stirring, (5) a large number may be prepared with practically the same labor as one for they may all be heated at once. M. W. G.



A Simple, Efficient Hydrogen Sulfide Generator. R. E. DUNBAR. *Chem.-Analyst*, **17**, 14 (Apr., 1928).—"The hydrogen sulfide generator described and illustrated, operating upon the general Kipp principle, is not essentially different from many described and illustrated elsewhere except in the nature of the laboratory apparatus used in the construction.

"This simple type of generator has proved most convenient in the inorganic laboratory, where it provides an abundant supply of readily available gas. It will deliver a remarkably large quantity of hydrogen sulfide to each charging. If properly constructed, there is little leakage, even immediately after closing the delivery tube, due to the formation of excess gas while the acid is draining from the calcium chloride tower. One generator of this type has also amply supplied six to eight students in regular courses in qualitative analysis. However, it does not deliver the gas under any great pressure, as may be desirable for the precipitation of the members of the tin group. The same generator may also be adapted to the production of other gases as hydrogen and carbon dioxide." M. W. G.

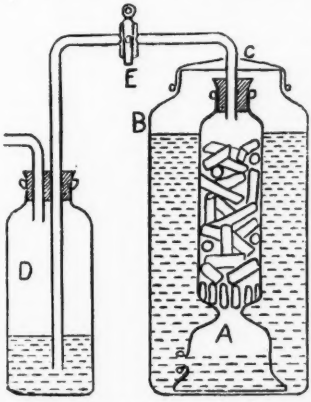


FIGURE 1—(*A*) calcium chloride tower, (*B*) wide-mouth bottle or salt jar, (*C*) loose cover with small opening for delivery tube, (*D*) wash bottle, (*E*) stopcock.

Solvent Economy in Extraction Work. CHAS. N. SHAW. *Chem.-Analyst*, **17**, 15 (Apr., 1928).—"When using the Soxhlet or similar type of extraction apparatus, a considerable portion of the solvent can be recovered for further use by the following method:

"After the extraction is completed, disconnect the reflux condenser and, after allowing to drain, remove the extraction thimble or cartridge from the largest size that will fit the extraction tube for the thimble, and reconnect to the reflux condenser. The solvent will then be caught in the tube which can be emptied from time to time, until most of the solvent has been driven from the residue. It is best, at this time, to disconnect the apparatus, for it is impossible to drive off the last traces of the solvent from the flask, unless its mouth is unobstructed, or unless a high heat is used, which is inadvisable.

"Where there is much extraction work done, or where expensive solvents are being employed, quite an appreciable saving can be affected." M. W. G.

A Non-Spattering Semi-Automatic Wash Bottle. NEO. S. SERINIS. *Chem.-Analyst*, **17**, 15–6 (Jan., 1928).—Figure 1 is a somewhat exaggerated sketch of the stopper holding the different passage tubes in their respective positions: *a*, bend for nozzle; *b*, rubber valve which regulates flow; *c*, check valve.

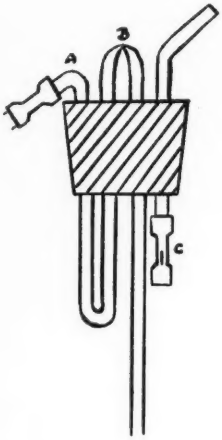


FIGURE 1

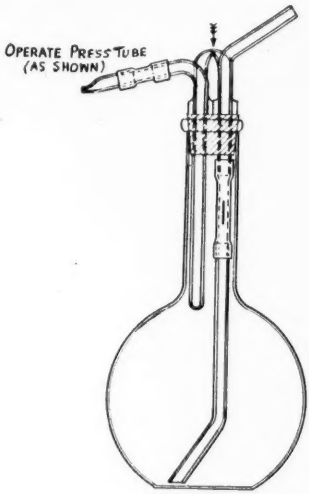


FIGURE 2

Figure 2 is a wash bottle complete as it ought to look when put together. Full directions for constructing and operating the wash bottle are included. M. W. G.

Automatic Wash Bottle. FRANK AMTHOR. *Chem.-Analyst*, **17**, 18 (Jan., 1928).—

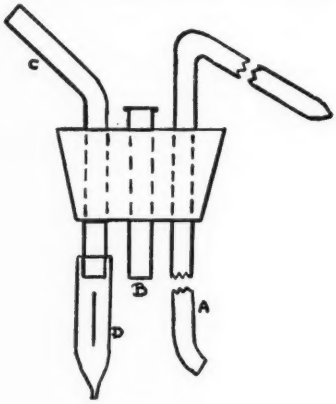


FIGURE 1

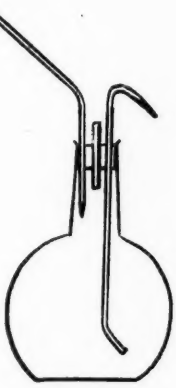


FIGURE 2

The accompanying drawings show an automatic wash bottle which may be quickly and easily made. Figure 1 gives the details of construction. *A* is the regular spout,

B is a glass tube, the top opening of which is covered by the thumb when using the bottle, *C* is the mouthpiece which has on its lower end *D*, a rubber policeman, slit with a razor blade. This slit policeman acts as an efficient valve to retain pressure in the bottle and so maintain a continuous stream without continuous blowing. Figure 2 represents the wash bottle fitted for use. M. W. G.

A Convenient Wash Bottle. C. J. SCHOLLENBERGER. *Chem.-Analyst*, **17**, 16 (Apr., 1928).—This wash bottle depends for its operation upon easily made glass valves in place of the ordinarily used perishable rubber parts. The method of making the glass valve is described.

"Pyrex tubing is best, but cannot be used unless an oxygen blast lamp is available. A piece of tubing, about 5 mm. inside diameter and at least 1 mm. wall, is heated in a very narrow zone about 15 mm. from one end in an intensely hot 'needle' flame, with constant rotation, causing the walls of the tube to thicken, then rolled upon a smooth piece of asbestos board to straighten and decrease the inside diameter to about 2.5 mm. The hot glass is annealed in a smoky flame. A piece of 2 mm. rod, longer than the tube, is heated and drawn out to about 1 mm. near one end, then melted off about 15 mm. from the narrowest point and a 4 mm. bead formed on the end. When cold, the other end of the rod is passed through the constriction in the tube, a little abrasive powder sprinkled on the wetted bead and the latter pulled in until stopped by the constriction. By twirling the other end of the rod between the finger and thumb the valve is ground to a seat. Unless the parts were very badly shaped, only a short time will be required for grinding. The valve is tested by washing off the abrasive and blowing the end. If tight, the rod with bead is removed and the bead broken off, together with a tail about 12 mm. in length. The bead is wrapped in filter paper and pushed down to its seat. After wrapping the constriction in paper also, to protect the ground part from the heat, the end of the tube above the bead is quickly heated at one spot and the softened glass pushed in with the point of a file, to such depth that the bead cannot fall out nor be caught. The hot glass is smoked for a moment to anneal. When cold, the charred paper is removed by immersing the valve in conc. H_2SO_4 with a little $K_2Cr_2O_7$ in a test tube and heating gently."

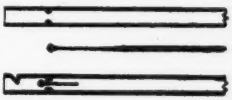


Figure 1

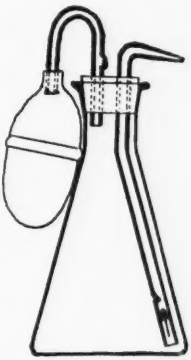


Figure 2

Such a valve may be substituted for the rubber Bunsen valves generally used in wash bottles. The valve, placed (reversed) at the bottom of the outlet tube, will prevent non-spattering, due to the fact that the delivery tube is always filled. The instant cut-off also prevents the annoying "after flow" of a few drops.

The form of wash bottle illustrated in figure 2 is suggested because of its convenience over the one requiring blowing by mouth. "The rubber bulb is a large oval pipet bulb, the bent glass tube connecting it to the flask is made of heavy walled tubing with a short side-arm at the proper place, to be closed with the forefinger when the bottle is in use, while the bulb is at the same time pressed with the thumb. The delivery tube is of the non-spattering form. A 300 ml. pyrex Erlenmeyer is a handy size for the flask although a larger one may be used if desired. If a large flask is used an atomizer bulb with valves is preferable to the pipet bulb." M. W. G.

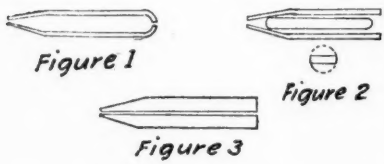
The Dripless Wash Bottle. H. SPURRIN. *Chem.-Analyst*, **17**, 15 (Apr., 1928).—"In the common quest for a dripless wash bottle, three very simple and efficient plans have been worked out that have some points to recommend them in addition to freedom from dripping.

"Figure 1—represents the common jet as usually made, but the rear end is closed down in the flame until its opening is only slightly larger than that at the tapered end.

"Figure 2—represents a jet as usually made with the addition of a flattened piece of glass rod, which serves to increase the internal friction in the jet and, as a consequence, of the angles existing between the body of the jet and the small insert; also the capillary effect which prevents dripping.

"In order to make the flattened piece, take a piece of glass rod small enough to

pass easily into the untapered portion of the jet and cut it off to such a length as indicated, being a little shorter than the jet. This small rod may be flattened on two opposite sides by rubbing it longitudinally on a metal or glass plate on which a little No. 120 carborundum and water have been sprinkled. This operation takes only a short time. The finished piece is indicated in the smaller drawing, figure 2, in cross section, the dotted part representing the ground-away portion. With a few endwise rubs on the grinding plate just used, the ends of this piece may be rounded ready for immersion into the jet as indicated.



"A third type of dripless jet is shown in figure 3. This is conveniently made from a piece of capillary glass tube of about 1 mm. bore (or larger if desired) as follows:

"Instead of drawing out the tube in the flame in the customary manner, grind the tube down gently on a fine carborundum wheel, traveling at high speed, or the same may be ground down on a wet grindstone, which takes longer but produces a nicely finished job.

"Any of these jets well repay one for the time occupied in making them by dint of the satisfaction experienced in using a cleanly tool. Of course, they can be used on the automatic or "Bunsen valve" bottle without in any way interfering with the automatic function or that of the jet itself.

"An added advantage is that they serve in a measure as a trap to hold back small suspended parts of an old rubber stopper that sometimes plug up a jet." M. W. G.

A Glass Stopper Remover. G. M. QUAM. *Chem.-Analyst*, **17**, 16 (Apr., 1928).—"The only excuse for adding this description of another stopper remover is that it is inexpensive and quite effective.

"Two round pieces of hard wood, smooth chair rounds serve very well, are placed on opposite sides of the stopper as indicated in Figure 1, and brought together by gripping firmly the ends of both rounds. A more convenient form may be made by placing an adjustable hinge at one end and operating the stopper remover somewhat like a nut cracker. The rounds can be shaped to remove stoppers of various types of bottles such as shown in Figure 2." M. W. G.

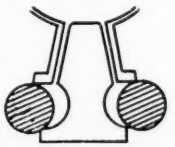


FIGURE 1

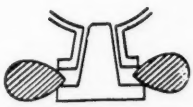
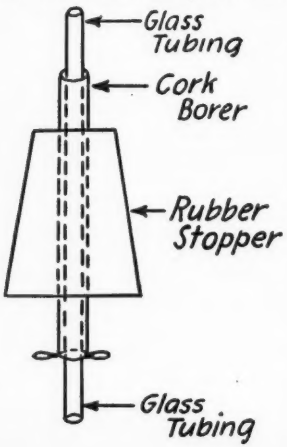


FIGURE 2



Insertion of Tight-Fitting Glass Tubing into Rubber Stoppers. T. J. COCHRANE. *Chem.-Analyst*, **17**, 20 (July, 1928).—"Having had difficulty in inserting glass tubing into holes in rubber stoppers where a tight fit was essential, the following scheme was hit upon.

After boring the hole to the desired size, the cork borer of the next size larger is forced through the hole already made. The glass tubing is now inserted into the cork borer within the stopper to the desired position, and the cork borer withdrawn, leaving the glass tubing in the position desired.

"This makes a safe and easy way to insert glass tubing into holes in rubber stoppers, and prevents to a large measure all the risks attending the inserting of glass tubing into rubber stoppers by the use of force." M. W. G.

An Improvised Photomicrographic Apparatus. CHAS. N. SHAW. *Chem.-Analyst*, **17**, 16–7 (July, 1928).—This apparatus consists of a studio type plate-camera mounted on a board directly above, the lens being in contact with the eye-piece of the microscope. A film-pack and film-pack adapter are

used instead of glass plates in plate-holders, due to the increased convenience in handling and filming the negatives, and the elimination of all chance of breakage. For illumination, a 250-watt 115-volt Mazda concentrated filament (stereopticon) lamp is used. At a magnification of approximately 200, an exposure of about 4 seconds has been found sufficient. Diagrams with full descriptions accompany article. M. W. G.

The Boiling Point and the Latent Heat of Vaporization of Water. J. B. NATHANSON. *Science*, **67**, 583 (June 8, 1928).—Many textbooks of physics leave the student with the impression that the boiling-point and latent heat of vaporization of water are "immutable constants." It is exceedingly difficult later to uproot this erroneous idea. G. H. W.

Tenth-Normal Sodium Hydroxide. C. J. SCHOLLENBERGER. *Chem.-Analyst*, **17**, 10–1 (July, 1928).—By following the method of preparation and storage described, "an exactly tenth-normal solution of the highest purity is prepared in somewhat more time, with but little more labor than would be required by the most careless procedure, and is finally delivered from the buret with every assurance that the strength is constant." M. W. G.

A Rapid Method for the Detection of Zinc in the Presence of Iron. WESLEY H. HAMMOND. *Chem.-Analyst*, **17**, 14 (Jan., 1928).—The article includes specifications for required solutions and directions for procedure. The advantages claimed for the method are: (1) does not require the preliminary separation of Fe, (2) is effective in a 1.2 sp. gr. electrolyte, (3) gives a characteristic colored ppt., (4) is specific for Zn as far as interference from the usual electrolyte impurities is concerned, (5) requires no more than five minutes for the test, (6) will detect as low as 0.0005% Zn. M. W. G.

Oxidation and Precipitation of Ferrous Compounds by Sodium Peroxide. FRED G. GERMUTH. *Chem.-Analyst*, **17**, 10 (Jan., 1928).—Advantages of the method over the generally used bromine-water one include: (1) oxidation of ferrous salt occurs during, and immediately following, precipitation; and (2) less time is required for completion of determination. The disposal of, or determination of, Al present in a sample is discussed. M. W. G.

Preparation and Standardization of Potassium Permanganate Solutions. R. P. HUDSON. *Chem.-Analyst*, **17**, 6–7 (Jan., 1928).—Explicit directions given. Some helpful directions on the determination of Fe in presence of HCl, and of P and Mn, volumetrically, by titration with the $KMnO_4$ solution, are included. M. W. G.

The Rapid Analysis of Mixtures of Barium and Calcium Salts. STANLEY KETTLE. *Chem.-Analyst*, **17**, 3 (Jan., 1928).—This method, directions for which are given, makes the analysis of the chlorides (and other soluble salts) of these two closely associated metals possible in one series of operations on one sample. M. W. G.

Sources of Free Material for Science Instruction. R. E. DUNBAR. *Gen. Sci. Quart.*, **12**, 551–6 (May, 1928).—Furnishes a compilation, collected, arranged, and revised by the author over a period of seven years. The material is of great value where there is a noticeable deficiency in laboratory or library facilities. The list furnished is valuable for those desiring industrial or educational exhibits and the accompanying bulletins. A general indefinite request for material is to be discouraged. School stationery should be used for writing for industrial exhibits. Four pages of a list of materials, where they can be procured, necessary cost, etc., in a few cases, are given. J. H. G.

The Use of Charts in the Natural Sciences. A. C. NOE. *Science*, **67**, 571 (June 8, 1928).—The author after inspecting and describing some of the newer German charts wonders if modern replacement of charts by lantern slides has not been carried too far. G. H. W.

EDUCATIONAL MEASUREMENTS AND DATA

Science in the New Curriculum. E. R. DOWNING. *Gen. Sci. Quart.*, **12**, 536–8 (May, 1928).—The North Central Association of Colleges and Secondary Schools has had at work for several years a large committee on the revision of the secondary school curriculum. The work of this committee is rapidly nearing completion. A sample of its work on general science and biology is submitted. The reports on science, including general science, biology, chemistry and physics, are available as a reprint from C. O. Davis, Ann Arbor, Michigan (University of Michigan). J. H. G.

Scales for Rating Pupils' Answers to Nine Types of Thought Questions in General Science. C. W. ODELL. *Gen. Sci. Quart.*, **12**, 524–36 (May, 1928).—Pupils' answers and Odell's criticisms are given to questions under type 7, Relationship, "What is the Relation of Sanitation to Disease?" type 8, Reorganization, "Trace the History of a Piece of Wood from the Tree to Its Use in a Piece of Furniture;" and type 9, Summary, "Give a Short Summary of the Process of Making Steel." J. H. G.

Objective Measurement in General Science. C. M. PRUITT. *Gen. Sci. Quart.*, **12**, 517–24 (May, 1928).—Reports the results obtained in standardizing Form A and Form B of the Powers General Science Tests. Three hundred pupils were used in the work. The validity and reliability of the tests were determined and certain correlation coefficients made. Reasons for the value of the tests for teachers and supervisors are given and six conclusions drawn. J. H. G.

An Analysis of Textbooks in General Science. O. E. OVERN, E. ILER, AND A. HEINEMANN. *Gen. Sci. Quart.*, **12**, 509–16 (May, 1928).—There is a detailed analysis of twenty-five General Science texts showing the space devoted to 20 large topics and 131 subdivisions of these. Maximum page space of each topic is shown. Analyses are tabulated. Then twenty texts are analyzed for principles and their applications. A thesis of Heinemann's shows that there is little unanimity among authors as to which science principles are of the greatest importance at the general science level in the schools. J. H. G.

KEEPING UP WITH CHEMISTRY

The Identification of Bios I as Inactive Inosite. *Can. Chem. and Met.*, **12**, 38 (June, 1928).—A brief account of the work of Prof. W. Lash Miller and his associates, and a short review of some of the previous work on Bios. "Inosite is a hexahydroxyhexahydrobenzine of the formula $C_6H_{12}O_6$. It has long been known as a constituent of plants but its remarkable significance was not previously understood or appreciated. Bios II remains undetermined but appears to consist of two separate substances. It must be present in the medium to ensure normal reproduction of the yeast which was used by the experimenters." D. C. L.

The Radioactive Elements. L. R. KELLER. *Sci. Mo.*, **27**, 54–6 (July, 1928).—A brief historical review of radium and its relation to the structure of matter is given. G. W. S.

Our Search for Chlorophyl and for the Vitamins. F. M. SCHURTZ. *Science*, **68**, 48–53 (July 20, 1928).—A short summary of work to date. A relation between light chlorophyl and vitamins is suggested. G. H. W.

Hemoglobin. J. BARCROFT. *Chem. & Ind.*, **47**, 609–17 (June 15, 1928).—The Messel Memorial Contribution. A valuable contribution to our knowledge of the subject, giving methods of making and purifying hemoglobin and of studying its actions in the life processes of various creatures. Very interesting results of spectroscopic studies of hemoglobin are given. E. R. W.

Temperatures. EDITORIAL. *Silicate P's & Q's*, **8**, 2 (July, 1928).—Man is a decidedly non-adaptable animal when the range of his temperature comfort is compared with that limited at one extreme by liquid hydrogen and at the other by the temperature of the atomic-hydrogen blowpipe flame.

Industry requires a greater temperature range for its operations than that comfortable to human life. Silicates of soda as bonding agents stand the extremes very well whether toward cold liquid hydrogen or at temperatures where the silicate fuses. Some care has to be exercised, however, through that part of this range where the silicate cement begins to lose water and just before it becomes sticky by fusion. By introducing other ingredients into the cement this deficiency can be corrected. However, not yet is it "possible to design silicate cements very much as an engineer designs a building from known data." B. C. H.

Silicates as Medicinals. EDITORIAL. *Silicate P's & Q's*, **8**, 2 (July, 1928).—Not a food, no, but even now sometimes used hypodermically for certain diseases. Silicate solutions have, by hospital trials, been found something like twenty times as capable in neutralizing organic acids as the next best preparation for a given alkaline intensity. Some stomach disorders require the neutralization of an acid condition. The alkali used for this "sweetening" action must not be strong enough to be harmful to body tissues. The property of alkali silicates which renders them safe for such stomach troubles also makes them good ingredients of soaps; *i. e.*, they exercise a modifying action upon the alkali so it will not harm the fiber of clothing. B. C. H.

The By-Product Fish Industry in Canada. R. T. ELWORTHY. *Can. Chem. and Met.*, **12**, 96–8 (April, 1928).—This article contains an account of the economic importance of the fishing industry and the procedure involved in the production of fish oil and fish meal. The value of fish oil depends on its appearance and certain constants. A chart is given showing the fatty acids present in various oils together with their constants. It describes the refining and deodorization of the oil and its hydrogenation. Hydrogenation is accomplished at 170 to 200°C. at 5 to 10 atmospheres pressure and the rate of hydrogenation followed by the change in iodine number or index of re-

fraction. A new method has been devised in which the nickel catalyst is placed in a gauze booklet and after being activated electrolytically, the oil and hydrogen are passed over it. This is still in the experimental stage. The various uses of the fish meal and oils are also given. D. C. L.

Edgar Fahs Smith. JAMES KENDALL. *Sci. Mo.*, **27**, 93–5 (July, 1928).—In a brief biographical sketch of Dr. Smith, K. pictures the personality of the man who, during his forty years of teaching and administrative work, gained the title of "the best-beloved college professor in America." G. W. S.

Sir Isaac Newton on Gravitation. FLORIAN CAJORI. *Sci. Mo.*, **27**, 47–53 (July, 1928).—In contrast to the lines of Alexander Pope that

Nature and nature's laws lay hid in night,
God said, "Let Newton be" and all was light.

C. shows that Newton had the work of such men as Kepler, Descartes, and Copernicus to build upon. Also, in contrast to the view held that Newton's delay in announcing his law of gravitation was due to an error in the value used for the earth's radius, C. believes the delay was caused by an uncertainty as to the distance to be measured in applying the gravitational hypothesis, should the distance be measured from the outside particle to the center of the earth or to some other point than the center? He finally proved that the distance must be measured from the center of the earth.
G. W. S.

THE PHILOSOPHY OF SCIENCE

The Fun of Being a Scientist. J. O. PERRINE. *Sci. Mo.*, **27**, 28–32 (July, 1928).—Levity and laughter are recognized as attributes of Will Rogersian jesters, but popular opinion gives them no place in the life of a research scientist. P. cites a number of instances in which great scientists have displayed enthusiasm and joy rivaling that of rooters at a football game. Galileo's amusement over the refusal of the professor of philosophy at Pisa to look through his telescope at the mountains and craters he had just discovered on the moon is but one of several exhibits cited. For a scientist there is no joy like working in his chosen field. "What have we to do with time but to fill it with labor, to work, to know, to discover and create." G. W. S.

THE METHODS AND PHILOSOPHY OF EDUCATION

College Entrance Requirements. WILLIAM L. W. FIELD. *Atlantic Mo.*, **142**, 84–6 (July, 1928).—A discussion of the old plan of requiring fifteen high-school units and the new plan, now recognized by thirty-seven colleges and universities in the U. S. This takes into consideration the amount and type of work done in high school which, if satisfactory, permits the applicant to take four examinations. These must be taken in one group which usually consist of one each in English, a foreign language, and mathematics or science. The list contains more than 200 approved combinations so that the applicant has considerable choice. F. believes the new plan is more truly in line with the statement that "higher education should represent an extension of secondary education; it is the progressive expansion of an essentially similar process. Admission to college is an institutional transfer within a homogeneous development." G. W. S.

Unity in Research. W. R. WHITNEY. *Sigma Xi Quart.*, **16**, 45–9 (1928).—Doctor Whitney designates "our accumulated knowledge" as large K or the integrated sum, "sigma" K, of all the infinitely small increments dk/dt. The large K, our so-called fundamental knowledge, may be largely variable, uncertain and even wrong at times. However, if dk remains positive there is hope. There is value to "change and dk."

In illustrating the importance of change and positive dk the author uses "six rather obscure research men:" Antonio Grimaldi, one of the earliest of cave men; Ashurnasim-pal, prominent about 875 B.C.; Democritus, the Greek philosopher who first conceived of atomic structure; John Woolman, a Philadelphia Quaker who hated slavery and saw smallpox as "a messenger from the Almighty to be an assistant in the cause of Virtue;" Emerson who eulogized "saliency of thought (as) a sort of importation and domestication of the Divine Effort in Man," and lastly the Seventh Duke of Devonshire who in 1871 gave $35,000 toward the establishment of the Cavendish laboratories at Cambridge, England. Each of these men represented a period which was an advance over that just preceding. Each and his contemporaries tried to "appreciate in a finite way a really infinite creation (even if but) by infinitely small increments." B. C. H.

Research and the Training of the Researcher. T. H. EATON. *Science*, **67**, 619 (June 22, 1928). G. H. W.

The Place of Science in Education. EDITORIAL. *Science*, **67**, 600 (June 15, 1928).—Extracts from report of a committee of the A. A. A. S. G. H. W.

THE TEACHING PROFESSION

Teacher Participation in Curriculum Research. R. E. RUTLEDGE. *High-Sch. Teacher*, **4**, 229–31 (June, 1928).—The teacher can aid in curriculum research by selecting and organizing means for achieving the educational objectives for his department of work. He has a most fortunate opportunity for discovering: appropriate child activities, child interests, the order of development of skills, and plans for recognizing individual differences by differing instruction. Examples of such research are described and a plan for administering such a project is outlined. B. C. H.

Suggestive Attributes of the Successful Teacher. F. THOMAS BECK. *High-Sch. Teacher*, **4**, 227–8 (June, 1928).—The attributes especially described are: friendliness, sympathy, enthusiasm, and forcefulness. The contention is put forth that these qualities can and should be cultivated. Other desirable attributes merely mentioned are: wit, humor, tact, resourcefulness, breadth of information, and habit of growth. B. C. H.

Sound Retirement. JOHN O. PETERSON. *Wash. Educ. J.*, **7**, 273 (May, 1928).—The reorganized retirement system would be a benefit to all teachers. Those who teach only a few years would have their money back, those who make teaching a life work would be contributing to a sound investment. The new system will keep the obligations of the present system. A. E. C.

Headquarters Retirement System. ANON. *J. Nat. Educ. Assoc.*, **17**, 182 (June, 1928).—Explanation of the retirement system is given. Membership will be limited to those on the permanent roll of the Association's headquarters staff. A. E. C.

More Teachers than Jobs. EDITORIAL. *Harvard Alumni Bull.*, **30**, 559–60 (Feb. 9, 1928).—Massachusetts reports an oversupply of trained teachers. Better quality must come. S. W. H.

A Method of Training Teachers in Service, the Dalton Laboratory Plan. L. L. W. WILSON. *Educ. Admin. & Superv.*, **14**, 117–22 (Feb., 1928).—The author discusses the values of the Dalton Plan from the viewpoint of pupils and teachers as it is used in the South Philadelphia High School. The following advantages are listed: (1) It compels better and ever better pedagogy. The teacher must see her subject from the child's viewpoint. (2) It compels more intelligent supervision and makes that supervision more efficient. With a minimum of visiting, a good department head knows exactly how the work is being done, whether it is functioning and why. He is in a position to give first aid and professional advice; the teachers are able to ask concretely and definitely for the help each may need. (3) It helps the teacher to discover causes of pupil difficulties. Many of them are curable. For example, the assignment of too much or too difficult work, failure to state details definitely and clearly, failure to provide enough work for the cleverer pupils and the like. (4) Teachers and departments can get a bird's eye view of the child and the school. They are then able to cooperate with both to their mutual advantage. (5) No longer do the teachers shrink from observation. How can they be self conscious in a laboratory atmosphere in which all teachers and pupils are working toward a definite goal? S. R. P.

MISCELLANEOUS

Research Plus News-Gathering. EDWIN E. SLOSSON AND WATSON DAVIS. *Science*, **67**, 628 (June 22, 1928).—*Science Service* has suggested that it coöperate with scientific organizations in checking the truth of reports of large news and apparent scientific values. Such coöperation has been authorized by the division of Anthropology and Psychology of the National Research Council, and other authorizations are pending. *Science Service* would like to extend its news gathering and research facilities and asks for suggestions. G. H. W.

Counting Molecules. MILES SHERRILL. *Tech. Rev.*, **30**, 335–6 (Apr., 1928).—Miles S. Sherrill, '99, in the Society of Arts Lectures on March 9th, 10th, 11th, said:

"Atoms and molecules can now be counted with more precision than the population of London. Neither the existence nor the reality of atoms is doubted any longer, for it is possible to determine the number of molecules in one gram molecular weight. This huge number is 6062 sextillion."

By means of the moving-picture camera the audience was shown the Brownian movement of colloidal mercury particles as seen through an ultra-microscope. Study of such motion makes possible the counting of molecules.

Later Professor Sherrill demonstrated a device known as the Geiger counter for counting α particles or electrons. S. W. H.

Local Activities and Opportunities

University of Mississippi. The following changes have been made in the Chemical Faculty. Dr. H. H. Johnstone has resigned to enter upon a research problem in the University of Illinois. His place is to be taken by Dr. John E. Foglesong of Trinity College, Hartford, Conn. Mr. J. A. Riddick, who is completing his work for the Doctor's degree at the Iowa State University this summer, is to join the Mississippi faculty as an added member.

University of Wisconsin. The University of Wisconsin announces the appointment of Professor A. Frumkin of the Karpow Institute of Chemistry of Moscow as Visiting Professor of Colloid Chemistry. He will join the staff of the Chemistry Department in September. Professor Frumkin is one of the leading colloid chemists of Europe and has made some very notable contributions in the fields of adsorption, electro-capillarity, and the various phenomena encountered at surfaces. At Wisconsin he will continue these researches with the assistance of graduate students, and will give a course of lectures in colloid chemistry. In the new addition to the chemistry building, now nearing completion, a suite of laboratories has been provided for the work in colloid chemistry. With the completion of these laboratories and the acquisition of Professor Frumkin, the University will be able to expand the work in colloid chemistry and to maintain its leadership in this field.

West Virginia University. In the department of chemistry at the West Virginia University, Associate Professor Hubert Hill has been raised to the rank of full Professor. Charles L. Lazzelle, Instructor, has been raised to the rank of Assistant Professor.

Appointments of graduate assistants for 1928–29 include Lucile Dunlap, A.B., Whittenburg College; M. S. Larrison, A.B., West Virginia University; Virgil G. Lilly, A.B., Pacific University, second-year appointment; H. B. Milligan, A.B., Hanover College, third-year appointment; Neva Palmer, A.B., West Virginia University; Kenneth Taylor, A.B., West Virginia Wesleyan College, second-year appointment.

W. H. Moran, A.B., West Virginia University, 1920; Ph.D., Ohio State University, 1923; Associate Professor of Bio-Chemistry at Baylor University, College of Medicine, Dallas, Texas; taught organic chemistry at West Virginia University during the second half of the summer school session, taking the place of Dr. C. E. Garland who was on leave.

University of Nebraska. The fellows and scholars appointed in the Dept. of Chemistry for the academic year, 1928–29 are listed below.

Fellows. Edward F. Degering, B.A., 1924, Union College, Nebr.; Sebastian A. Durban, M.Sc., 1926, Univ. of Texas; Edwin A. Fluevog, A.B., 1926, Univ. of N. Dak.; M.Sc., 1928, Univ. of Nebr.; Edwin L. Mattison, A.B., 1926, S. Western.

Scholars. Howard T. Bonnett, A.B., 1928, Baker Univ., Baldwin, Kans.; Mabel Louise Donley, A.B., 1925, Univ. of Nebr.; Ruth B. Eidem, A.B., 1928, S. Dak. State College, Brookings; Clyde W. Eddy, B.Sc., 1928, S. Dak. State College, Brookings; Franklin E. Golden, A.B., 1927, S. Western College, Kans.; Vincent Frank Hnizda, B.Sc., 1928, Univ. of Nebr.; Clarence Milton Iwen, A.B., Lawrence College, Appleton, Wis.; Carl Christian Jensen, B.Sc., 1928, Univ. of Nebr.; Marvin Dee Knoll, A.B., 1926, Union College; Albert Lightbody, B.Sc., 1928, Chadron State Normal College, Nebr.; Wm. Dayton Maclay, B.Sc.,

1928, Univ. of Nebr.; Clare Prather, A.B., 1921, S. Western College, Kans.; Warren H. Steinback, B.Sc., 1926, Hastings College, Nebr.; Paul Russell Shildneck, B.Sc., 1928, Univ. of Nebr.; George H. Wilder, B.Sc., 1928, Univ. of Nebr.

Carnegie Institute of Technology. Dr. John Johnston, director of research and technology of the United States Steel Corporation; C. A. Reinhardt, chief metallurgist of the Youngstown Sheet and Tube Company; Dr. A. J. Unger, manager of the research bureau of the Carnegie Steel Company; and Homer D. Williams, president of the Pittsburgh Steel Company, have been invited by President Thomas S. Baker to become members of the advisory board of the department of metallurgical engineering at Carnegie Institute of Technology, it is announced.

The advisory board, which is composed of about 25 steel company executives and metallurgists, is concerned primarily with the development of metallurgical research as now carried on jointly by the Carnegie Institute of Technology and the U. S. Bureau of Mines. Several important studies in ferrous metallurgy have been made under these auspices during the past few years. T. D. Lynch, consulting metallurgical engineer to the Westinghouse Electric and Manufacturing Company, is chairman of the board for the coming year.

Other members are: F. B. Bell, President, Edgewater Steel Co.; Dr. Earl Blough, Technical Director, Aluminum Company of America; B. V. Brown, General Superintendent, Allegheny Steel Co.; C. A. Buck, Vice-President, Bethlehem Steel Co.; Roy H. Davis, Pittsburgh; George H. Faunce, President, Pennsylvania Smelting Co.; T. M. Girdler, President, Jones and Laughlin Steel Corp.; S. A. Grayson, President, Jessop Steel Co.; J. O. Handy, Director of Special Investigations, Pittsburgh Testing Laboratory; C. W. Hoppenstall, President, Hoppenstall Forge and Knife Co.; Charles R. Hook, Vice-President, American Rolling Mill Co.; E. T. McCleary, President, Republic Iron and Steel Co.; W. E. Moore, Consulting Engineer, Pittsburgh Electric Furnace Corp.; C. F. W. Rys, Assistant to President, Carnegie Steel Co.; Isaac M. Scott, President, Wheeling Steel Corp.; S. G. Stafford, Vulcan Crucible Steel Co.; F. N. Speller, Chief Metallurgical Engineer, National Tube Co.; Kenneth Seaver, General Sales Manager, Harbison-Walker Refractories Co.; J. C. Williams, Vice-President, Weirton Steel Co.; and R. B. Zimmerman, Assistant to Vice-President, American Sheet and Tin Plate Co.

For the coming year, it is announced, the advisory board has selected a program of five investigations in ferrous metallurgy to be made by Research Fellows under the auspices of the Carnegie Institute of Technology and the Bureau of Mines. An advisory board of coal-mine operators and engineers, which occupies a similar relationship to the department of mining engineering, has selected six problems in fuel chemistry for investigation by six college graduates ranked as research fellows for the coming year.

.....

Twelve major topics for discussion at the Second International Conference on Bituminous Coal, to be held under the auspices of the Carnegie Institute of Technology, Pittsburgh, Pa., November 19–24, 1928, are tentatively announced by Dr. Thomas S. Baker, president of the institution, and chairman of the Congress. About one hundred engineers and scientists representing fifteen nations have already tentatively accepted invitations to speak or to send papers to the Congress, and the number of speakers and delegates is growing daily. About sixty per cent of the papers will be delivered by representatives of countries other than the United States.

Although the Second International Conference will be similar in purpose to the first Congress held in 1926, preliminary plans for this year's meeting show that its scope will be considerably enlarged and the program will be more important and more international in character. The

discussion of Fixed Nitrogen is one of the topics which will receive close attention. The liquefaction of coal, which was one of the principal subjects of discussion at the first meeting, will again occupy a prominent place in the deliberations. Low-temperature distillation will be treated by representatives of at least a half dozen countries. High-temperature distillation, power from coal, coal tars and oils, complete gasification of coal, origin of coal, coal washing, pulverized coal, catalysts, and the general aspects of the bituminous coal industry are other topics that will be considered.

Among the outstanding Europeans who are expected to attend the Congress are Donat Agache, E. Audibert, Jean Bing, Emile Heurteau, Antonie Vonk, Paul Weiss, Henri Winckler, and Raymond Borr, France; Dr. Franz Fischer, Professor Fritz Hoffman, Professor F. P. Kerschbaum, Dr. Carl Krauch, Dr. Friedrich Bergius, Rudolph Pawlikowski, Professor Ernest Terres, Professor Dr. Glinz, Dr. J. E. Noeggerath, Joseph Plassmann, Rudolph Battig, Dr. Karl Bunte, and Professor Fritz Frank, Germany; Lord Melchett (Sir Alfred Mond), Dr. Cecil H. Lander, Harald Nielsen, Colonel Lindemann, Dr. R. Lessing, and Edgar C. Evans, England; Commendatore Alberto Eduardo Bianchi and Engineer Guardabassi, Italy; Professor Dr. Granigg, Austria; A. France, Belgium; Professor P. E. Raaschou, Denmark; Professor H. Kling, Poland; Professors George L. Stadnikoff and L. K. Ramsin, Russia. Japan will be represented by Professors Yoskikiyo Oshima and Chozo Iwasaki. Delegates will also come from Czecho-Slovakia, Canada, Norway, Spain, Chili, Roumania, Jugo-Slavia, and Bulgaria.

The Economics of the Coal Industry will be discussed by Lord Melchett, Dr. Friedrich Bergius, Professor Dr. Franz Fischer, Germany; Andre Kling and E. Audibert, France. Engineer Guardabassi, Italy, will deal with the subject of the liquefaction of coal.

Low-Temperature Distillation will be treated by George E. K. Blythe, Dr. C. H. Lander, Harald Nielsen, Dr. E. W. Smith, England; Dr. A. Herz, Joseph Plassmann, Professor F. P. Kerschbaum, Germany; Henri Lafond, Professor Paul Lebeau, Antonie Vonk, A. Leante, France; Professor Dr. Granigg, Austria; Professor Yoskikiyo Oshima, Japan; Professor Samuel W. Parr, Professor Alfred H. White, and F. C. Greene, United States.

High-Temperature Distillation: Jean Bing, France; Professor Ernest Terres, Germany; Edgar C. Evans, England.

Power from Coal: Dr. J. E. Noeggerath, Germany; C. Simon, France; A. T. Stuart, Canada; W. B. Chapman and Professor A. G. Christie, United States.

Coal Tars and Oils: Henri Winckler, France; Dr. L. Edeleanu and Professor Dr. Fritz Frank, Germany; and Gustaf Egloff, United States.

Gasification of Coal: Dr. Karl Bunte and Dr. Alfred Pott, Germany; Paul Weiss, France.

Origin of Coal: Professor George L. Stadnikoff, Russia; Dr. Chozo Iwasaki, Japan; Dr. Reinhardt Thiessen and Professor E. C. Jeffrey, United States.

Fixed Nitrogen: A representative of L'Air Liquide Societé, France; Rudolf Battig, Germany; Professor Harry A. Curtis, Louis C. Jones, and Charles J. Brand, United States.

Coal Washing: A. France, Belgium; Professor Dr. Glinz, Germany; Dr. R. Lessing, England; F. R. Wadleigh, Dr. F. W. Sperr, James B. Morrow, and Byron Bird, United States.

Pulverized Coal: Dr. I. P. Goosens, Rudolph Pawlikowski, and Dr. P. Rosin, Germany; C. J. Jefferson, United States

Catalysts: Professor A. Mailhe, France; Professor Hugh S. Taylor, United States.

Rubber from Coal: Professor Fritz Hoffmann, Germany.

Addresses not yet classified under these headings will be given, it is expected, by F. S. Sinnatt, England; Raymond Berr, France; P. E. Raaschou, Denmark; John Hays Hammond, Howard N. Eavenson, E. E. Slosson, Dr. Arthur D. Little, A. C.

Fieldner, and Dr. H. C. Parmelee, United States.

The list of speakers, it is pointed out, will be considerably enlarged during the coming months. President Baker and his associates planning the Congress expect to announce the final program details in October.

In addition to the above scientists a large number of prominent American industrialists and financiers will be present at the Congress. There were nearly 1800 delegates at the Conference in 1926 and it is expected that the meeting of 1928 will be more largely attended.

The members of the Advisory Board for the Congress are John Hays Hammond, Distinguished American Engineer; E. M. Herr, President, Westinghouse Electric and Manufacturing Company; Samuel Insull, Capitalist; Frank B. Jewett, President of the Bell Laboratories, Inc.; Otto H. Kahn, Capitalist; George E. Learnard, President, International Combustion Engineering Corporation; A. W. Mellon, Secretary of the Treasury; Auguste G. Pratt, President, Babcock & Wilcox Company; H. B. Rust, President, Koppers Company; Charles M. Schwab, Chairman, Bethlehem Steel Corporation; W. C. Teagle, President, Standard Oil Company, New Jersey.

Mellon Institute Technochemical Lectures, 1928–1929. Two series of lectures on important subjects in industrial chemistry and chemical engineering will be presented by technologic specialists of Mellon Institute of Industrial Research during the University year 1928–1929. These discourses, which will be delivered on Mondays, in the fourth period (11.30 A.M–12:30 P.M.), throughout both semesters, in the Fellows' Room of the Institute, will be open to all students of industrial chemistry and chemical engineering in the University of Pittsburgh, as well as to all the Institute's members. They will also be open, on special permission, to other qualified students of the University and to chemists and teachers of chemistry of the Pittsburgh district.

Introductory Lecture

1928

October 1.—Dr. Edward R. Weidlein: "Chemical Engineering, the Directional Force of Chemical Industry"

First Series: Lectures on Some Important Chemical Engineering Materials

(Their Manufacture, Properties, Uses and Evaluation)

October 8.—Mr. S. M. Phelps: "The Manufacture of Refractories"

October 15.—Mr. S. M. Phelps: "The Properties of Refractories"

October 22.—Mr. S. M. Phelps: "The Uses of Refractories"

October 29.—Mr. C. H. Geister: "The Manufacture of Lime"

November 5.—Mr. C. H. Geister: "The Properties and Uses of Lime"

November 19.—Mr. Tracy Bartholomew: "The Manufacture of Portland Cement"

November 26.—Mr. Tracy Bartholomew: "The Properties and Uses of Portland Cement"

December 3.—Mr. Henri Marc: "Asbestos and Magnesia Products"

December 10.—Mr. R. H. Heilman: "Heat Insulation Materials"

December 17.—Mr. B. A. Rice: "Vitreous Enamels"

1929

January 7.—Dr. E. E. Marbaker: "Cast Iron"

January 14.—Mr. H. K. Work: "Aluminum and Its Useful Alloys"

January 21.—Dr. B. B. Westcott: "Special Corrosion-Resistant Alloys"

Second Series: Lectures on Professional Opportunities in Various Industries

(Inspirational talks on what the chemist and chemical engineer have done, are doing, and can probably accomplish in these fields)

1929

February 11.—Mr. R. E. Arnold: "Clay Products"

February 18.—Mr. E. J. Casselman: "Glass"

February 25.—Dr. W. A. Gruse: "Petroleum Refining"

March 4.—Mr. O. O. Malleis: "By-Product Coke"
March 11.—Mr. E. W. Reid: "Olefin Products"
March 18.—Dr. W. B. Burnett: "Naval Stores"
March 25.—Dr. P. B. Davidson: "Paper"
April 8.—Dr. H. L. Cox: "Explosives"
April 15.—Dr. R. B. Trusler: "Fatty Oils and Soaps"
April 22.—Dr. G. S. Hiers: "Dyes"
April 29.—Mr. G. H. Johnson: "Textiles"
May 6.—Mr. H. K. Salzberg: "Paints"
May 13.—Dr. G. D. Beal: "Fine Chemicals"

Lexington Regional Meeting, A. C. S. The Ohio, Michigan, Lexington, Ky., and Erie, Pa., Sections of the American Chemical Society will hold their seventh Regional Meeting at Lexington, Ky., October 26 and 27, 1928. Invitations have been extended to other sections so that chemists from twelve local organizations of the four states will assemble at this meeting. The sessions will be held at the University of Kentucky in the recently completed chemistry building, which appropriately bears the name, Kastle Hall, in honor of a beloved and eminent professor of chemistry, the late Dr. Joseph Kastle.

The following committees have been announced to take charge of this regional meeting: *Program*, V. F. Payne, J. S. McHargue, J. S. Pierce; *Registration*, Charles Barkenbus, J. R. Mitchell, R. I. Rush, A. J. Zimmerman; *Entertainment*, F. E. Tuttle, H. D. Spears, L. A. Brown. The Regional Chairman, R. N. Maxson, University of Kentucky, Lexington, and the Secretary, V. F. Payne, Transylvania College, Lexington, are members, ex-officio, of all Committees.

The guest speakers out of the Region already engaged are President S. W. Parr, who will speak on "Coal Carbonization," and Professor W. D. Harkins, whose lecture subject will be "Surfaces and Their Importance."

The University of Kentucky takes a real pride in acting, in a measure, as host of the Regional Meeting and extends to all the courtesies for which this region is famous.

Chemistry in Transylvania University, 1799–1860. Transylvania is one of the oldest schools in the middle west and its library contains a wealth of historical chemistry which will be of great interest to those attending the LEXINGTON REGIONAL MEETING, October 26 and 27, 1928. The following notes on early chemistry at Transylvania are furnished by the librarian of that institution (*Isotopics*, **4**, 7, 11 (April, 1928)).

Chemistry was first taught in Transylvania University in 1799 by Samuel Brown, M.D., professor of chemistry, anatomy, and surgery in the department of medicine. At a meeting of the board of trustees on December 11, 1799, it was resolved, "That Dr. Samuel Brown be authorized to import such medical books as shall be deemed proper by the professors of medicine for the use of the University, the amount expended not to exceed $500."

Preserved in the archives is a bill, dated 1800, for books purchased by Dr. Brown for the university. In this list the books on chemistry are: Bergman's "Chemical Essays," 2 vols., one pound, ten shillings; Lavoisier's "Chemistry," one pound, three pence; Bishop Watson's "Chemical Essays," 2 vols., one pound, ten shillings.

The Rev. Harry Toulmin, president in 1794 of Transylvania Seminary, was a friend and, in religious thinking, a follower of Joseph Priestley. An Englishman, Mr. Toulmin espoused the cause of the French revolutionists, and migrated to America with Priestley in 1793. This association of the great chemist and Transylvania's president probably accounts for the presence in the Transylvania library of a volume of Keill's "Philosophical Lectures," London, 1758, on the title page of which is Joseph Priestley's autograph. It may account, too, for the purchase in 1795 of two of Priestley's works for the Seminary. In a bill of that date for books bought of Matthew Carey of Philadelphia are these items: "Priestley on Air," 2 vols., two

pounds, five shillings; "Priestley's Letters to the Jews," four shillings, six pence.

An interesting link with Thomas Cooper, another early chemist, are letters of 1815 and 1816 relating to his call to the chair of chemistry in Transylvania and later to the presidency. Cooper's "Conversations on Chemistry" and his "Treatise on Dyeing" were early purchases for the academical library.

Of the library of the old Transylvania University preserved today there are more than five hundred volumes relating to chemistry. Very important among these and seemingly rare in America are "Annales de Chimie," Paris, 1798 to 1845, vols. 1 to 75, and new series, vols. 1 to 15.

In January, 1823, Robert Best, M.D., professor of chemistry in the medical college, published a brochure of seventy-five pages, "Tables of Chemical Equivalents," in which was included a "Note on Vegetable Poisons," by Daniel Drake. Important contributions were made to the literature of chemistry by another professor, Thomas D. Mitchell, M.D. In the decades just preceding the Civil War Dr. Robert Peter ably supported the high standard always held in the teaching of chemistry in Transylvania. In later years Dr. Peter was transferred to the University of Kentucky. Throughout his career he was probably the greatest single force in the field of chemistry in Kentucky.

Cellulose Content New Basis for Forest Ratings. Cellulose, the stuff that rayon and print-paper and brushing lacquers and smokeless powder are made of, will set the future valuation on forests, rather than the old-fashioned estimate of the number of board feet they will yield at the sawmill. This was the prophecy of Dr. A. W. Schorger of Madison, Wis., before the recent Institute of Chemistry of the American Chemical Society.

"Wood for structural purposes is being supplanted rapidly by other materials which are as good or better for the purpose," the speaker declared. "For cellulose, however, there is no substitute. Wood must be relied upon to furnish the bulk of the cellulose, particularly where the fibrous properties are paramount.

"Field crops as a source of cellulose should be viewed with conservatism, since many of the cellulose aggregates, particularly the pith cells, are so short as to be unsuited to the manufacture of paper products, for which most of the cellulose will be consumed for years to come. Well-managed woodland will produce 2000 pounds of cellulose per acre per year, while the average yield from an acre of cotton is only 155 pounds."—*Science Service*

Search for Synthetic Rubber Helps Chemistry, though It Fails. "The quest for synthetic rubber may be compared to the quest for the Golden Fleece, the Fountain of Youth, or the Philosopher's Stone, in so far as the objective appears exceedingly unlikely of attainment, but the quest has been very fruitful in secondary results for the general improvement of rubber technology and scientific knowledge." This was the theme of Thomas Midgley, Jr., of Dayton, Ohio, noted as the inventor of ethyl gas, speaking before the Institute of Chemistry of the American Chemical Society at Evanston, Ill.

Rubber is, chemically speaking, a multiplication of an organic compound known as isoprene, and many attempts, some of them successful on a laboratory scale, have been made to make rubber out of this substance. But none of these isoprene rubbers have the stretch and bounce and other physical qualities needed for full-fledged commercially successful rubber. In the investigation of the differences between the artificial and the natural products, however, chemical discoveries have been made that now have wide application in rubber manufacture and in certain other industries as well.—*Science Service*

Recent Books

Introduction to Physiological Chemistry. MEYER BODANSKY, Ph.D. John Wiley and Sons, Inc., New York City, 1928. 1st edition. vii + 440 pp. 44 figures, xxxii tables. 15 × 23 cm. $4.00.

The word Introduction appearing in a title conventionally leads one to associate with it the idea of elementary. In the book under consideration the introduction is decidedly not at the beginning of the subject. For instance, in the chapter on Enzyme Action there is a discussion of monomolecular and bimolecular reactions; the chapter on Animal Calorimetry is introduced with a thermodynamic development and the chapter on Blood and Lymph devotes considerable attention to the highly specialized and intricate conception of the various possibilities for compensated acidosis depending on the level of blood alkali available. The book is scarcely an elementary one.

To cover the field of what is known as physiological chemistry is a large task and, in order to confine the material in one volume of reasonable textbook size, the author has had to make the style rather sketchy, with discussion limited to the bare essentials. This fact shows that the science of physiological chemistry has developed into a definite entity. The material usually included in textbooks of biochemistry is present with the exception of the chemistry of the tissues. Intermediary metabolism is given especially good treatment and there are chapters on nutrition, physiological oxidation and the endocrine organs.

A good textbook should not only be a summary of fundamental information up to the time of writing but should also represent some synthetic effort on the part of the author. The subject-matter in this book has been brought decidedly up to date and copious references are given at the bottom of the page where they belong. The book is well written and throughout shows a conscious effort on the part of the author to clarify the conception of certain fundamental principles such as, for example, hydrogen-ion concentration, Donnan equilibrium and specific dynamic action. Tables and charts are used extensively and to advantage and the typography is excellent.

ARTHUR H. SMITH

Laboratory Manual of Physiological Chemistry. MEYER BODANSKY AND MARION S. FAY. John Wiley and Sons, Inc., New York City, 1928. First edition. vii + 234 pp. 9 figures. 15 × 23 cm. $2.00.

In a useful laboratory manual, perhaps as important as the content, is the availability of the material which, in turn, depends largely on its arrangement. In the present volume the authors have shown considerable skill in presenting the various parts of the experimental procedure. The student can find the details of manipulation, the directions for making reagents and the principle of the method all together on one page, yet without confusion, due, partly, to the skilful use of footnotes.

The authors in the preface acknowledge the difficulties in attempting to supply the ideal biochemical laboratory manual. The result, however, is a very happy one both in the inclusion of new material and in the lucidity of presentation of the older conventional experiments. The use of occasional quantitative experiments along with the more strictly qualitative material adds interest for both instructor and student. It is unfortunate that the rather extensive adaptations of the Van Slyke constant volume gasometric apparatus have been omitted. The use of references to the

source material is commendable as is the workmanship of the book.

ARTHUR H. SMITH

The Normal Diet. W. D. SANSUM. The C. V. Mosby Company, St. Louis, 1927. Second edition. xiv + 136 pp. 13.25 × 19.75 cm. $1.50.

The purpose of the book "The Normal Diet" by W. D. Sansum is well expressed in the following—"Dedicated to An Effort to Prevent Illness, Relieve Suffering, and Prolong Life through the Proper Use of Food." The book includes a discussion of the following fundamental principles underlying the selection of a normal diet. (1) Bulk requirements of the body; (2) acid-ash and acetone types of acidosis; (3) caloric requirements of the body; (4) protein requirements of the body; (5) mineral requirements of the body; (6) vitamin requirements of the body; (7) water requirements of the body. In addition to the simple statements of the fundamental principles underlying the selection of a normal diet, not only a variety of normal diet menus but also a group of special menus are presented. These illustrate the adaptation of diets both for normal physiological conditions and for various nutritional disorders. Lists of references to nutritional literature are also included.

The author has presented in "The Normal Diet" a wealth of material of scientific recognition in a manner available to the layman. It has been demonstrated that a consistent attempt to follow the dietary regime presented by the author does prevent suffering from the various nutritional disorders. Dr. Sansum has had sufficient experience so that the data and suggestions offered are of unusual value.

The author has unfortunately retained the old spelling "vitamine" instead of "vitamin," but has presented a most concise, accurate, and inclusive discussion of the subject.

The author gives in "The Normal Diet" the best presentation available of the acid and alkaline characteristics of foods and the response of the body to these foods. The chapters on the acid-ash and acetone types of acidosis are undoubtedly of the greatest value.

"The Normal Diet" is to a considerable extent a popular book although definitely based on scientific literature. It includes a resumé of the fundamental principles of physiology and physiological chemistry so expressed that they may be understood by the intelligent layman, and thus presents to him a means of understanding more about the chemistry of life. To the scientist, too, and to the student, particularly, of Home Economics and of Medicine, "The Normal Diet" presents an excellent review of material fundamental to the understanding of the choice of a diet which will promote and allow normal physiological activity.

ROSALEENE ARNOLD HETLER

General Chemistry. AZARIAH T. LINCOLN AND GEORGE B. BANKS. Prentice-Hall, Inc., New York City, 1928. xvi + 681 pp. 133 illustrations. 23 × 15 cm. $3.50.

The text under review is essentially of the descriptive type, as contrasted with those books which emphasize the teaching of the principles of chemistry and their applications. This is shown by the extensive discussion of the importance of chemistry to daily life and the industries, by the use of an unusually large number of excellent photographs and diagrams of chemical apparatus, and by the large amount of space devoted to organic chemistry, which occupies about one-fourth of the text. In fact, the descriptive material is so full that the text in parts becomes almost encyclopedic; thus, in the chapter on the halogens, from 50 to 60 halides are described with respect to color, hydration, hydrolysis, etc., and similar lists of other salts and of oxides are to be found elsewhere.

This elaboration of descriptive details necessarily leads to drastic curtailment of the space given to the principles of chemistry. Chapter XI, for example, com-

prises only 10 pages of the text, yet it takes up in addition to a general discussion of the value of theories and their limitations, the molecular and atomic theories, including molecular and atomic weights, chemical and physical change, radicals, structural formulas, crystal structure, and the phlogiston theory. It is therefore not surprising that the theoretical matter in general fails to become an integral part of the text; thus, there is one chapter on ionization but thereafter one finds practically no mention of ions, no ionic equations, no interpretations of reactions on the basis of the theory of ionization. Such a treatment of general chemistry makes necessary the explicit description of many facts which ought to be implied, were the student trained to apply the principles of chemistry to the behavior of simple substances.

The use of the electrochemical series as a guide in the organization of the material seems to have led to a considerable amount of difficulty, for this order is not followed throughout. When another arrangement is substituted, the groups of qualitative analysis are used instead of the families of the periodic system. This seems unfortunate to the reviewer because it emphasizes relations based on the solubility of a few selected compounds and neglects the more fundamental relationships of chemistry. Also, the use of the electrochemical series has here resulted in an overemphasis of the polar concept of valence; that there is a marked difference between polar and nonpolar compounds is nowhere brought out.

There have crept into the book, which contains so much excellent descriptive material, a number of inaccurate statements. For instance, oxygen is called the most negative and fluorine the most energetic element; energy is defined as the power of a substance to cause change; the increase of reaction velocity with rise of temperature is explained solely on the ground of increased kinetic energy of the molecules. In many respects also the interpretations of phenomena have not been brought up to date; the newer views concerning degree of ionization are not mentioned, the equilibrium constant is illustrated by a reaction involving strong electrolytes without considering their dissociation, the old method of partial equations, which in one case involves six steps, is used throughout for balancing reactions of oxidation and reduction.

The book is well set up, with large type that makes for easy reading and is remarkably free from typographical errors.

H. I. SCHLESINGER

An Introduction to General Chemistry. WILLIAM MARTIN BLANCHARD. Doubleday, Doran and Company, Inc., Garden City, New York, 1928. vi + 588 pp. 11 illustrations, 8 charts, 90 figures. 21 × 14 cm. $3.00.

The book is attractively but only fairly well bound. The page type is 10 on 12 Century and is very easy on the eyes. The paper is of a good quality; however, ink "runs" slightly on it. The impress is excellent as there are but few instances of broken type. The volume is also almost entirely free from typographical errors.

There is no statement in the book as to whether or not it is intended alike for those who have and those who have not studied chemistry in the high school. Although this is the first edition, the author has had previous experience in the preparation of a chemistry text. In addition, he is an experienced and sympathetic teacher and his latest product has correspondingly profited therefrom. The fact that the manuscript was read by Professors R. A. Baker, Louis Test, and F. B. Wade is also prophetic. Professor Blanchard frankly admits that he "has consciously used the difficulties encountered by the average college student in the study of chemistry as his guide." He "has taken special pains to help the student over such troubles as the Oxygen Acids of the Halogens, the Periodic System—Oxidation and Reduction—and the Colloidal State—the aim has been to interweave theory and practice so that the student may understand the *meaning* of chemistry." The book has the

human touch as is well evidenced in several places (*e. g.*, see p. 395 on lithium salts; also p. 241 on ozone). In the early chapters, before the author is ready to give the chemical details of certain methods involved, he prevents the student having heart failure by the use of "a suitable method." Appropriate employment is made of editorial "we" which is more likely to cause the student to feel that he is really having a rôle in the course. The student's interest is of a necessity aroused by (p. 192) "We must now resume our study of the elements and their more important compounds. In what order shall we take them?" and (p. 51) "But how can we find this (atomic weights) out?" The presentation and frequent utilizations of "solubility product" are deserving of commendation. The 374 questions and problems will require quite a little cogitation on the part of the user.

Although certain chapters, such as the ones on formulas, equation writing, valence, and atomic theory, are introduced earlier than in some texts, their presentation is done in such an unostentatious manner that the student is not likely to be frightened. The material on radium and radioactivity is properly a part of the study of the atom and the periodic law.

The absence of a definition or discussion of such terms as allotropes, peroxide structure, amphoteres, and condensed acids may be meritorious. CS_2 is named "carbon bisulfide" and BaO_2, "barium dioxide (peroxide)." The treatment of valence (p. 74–5) is inadequate. The writer is not in sympathy with the author's use of $=$, $\longrightarrow$ and $\rightleftarrows$ in equation writing, believing that the former should be in the discard. It is to be regretted that the efforts of the American Chemical Society are not supported in the spelling of sulfur, aluminum, pipet, and buret. The distinction between "charts" and "figures" is inconvenient to the reader. An appendix of certain physico-chemical tables, particularly of atomic weights, would not be unwelcome. The book is worthy of better executed drawings. The eleven illustrations of chemists are extraordinarily good and suitable for framing. A few cuts showing the commercial side of chemistry would be worthwhile. Some of the descriptive material should be in smaller type. The author has been fairly successful in avoiding a compendium. Despite the above shortcomings, the book as a whole compares favorably with the better known first-course texts of chemistry.

J. E. DAY

Atomstruktur und Atombindung. J. STARK. o. Universitat professor fur Physik. Polytechnische Buchhandlung, A. Seydel, Berlin, 1928. First edition. xx + 198 pp. 16 cuts. 14 × 22 cm. Rm. 9.

This book presents an exposition of a very comprehensive theory, developed by the author, concerning the structure of atoms and the linking of atoms in molecules. Many will feel much in sympathy with his assumption of a static atom that is static in that the central points of the electrons have fixed positions. Few will find fault with his claim that the atom possesses an axis, in fact, not only the atom but each electron and proton (archion). He finds it unnecessary to postulate an ether but he does surround electrons and protons with electrostatic and electromagnetic fields and endows them with "inner kinetic energy." As a resultant of the electromagnetic, electrostatic, and inner kinetic forces, certain discrete equilibrium positions result. If only slightly disturbed, the electron returns to its equilibrium position but with a great enough disturbance it may fall to another equilibrium position, the energy difference between these positions being disposed of quite in accord with the quantum theory.

The electrons are built up in layers around the nucleus in a fairly conventional fashion except that the layers possess certain eccentricities peculiar to this theory. The electrons of the outermost layer constitute the valence electrons.

The nucleus is built, much in the same

fashion as the electron shell, out of succeeding layers, not of electrons, but of individuals termed "helions" consisting of one electron and two protons (archions) each. These are not stable in free space but only in the strong force fields within the nucleus.

Whatever satisfaction one may feel at the fixed location of the atom constituents is shattered when one comes to the explanation of isotopes and radioactive phenomena. In the powerful electromagnetic field in the space between nucleus and inner layer of electrons (zwischenraum) still another kind of individual, the neutron, consisting of one electron and one proton, may exist. Of the neutrons there may be any number within wide limits and they are all in rapid and disorganized motion. In their chance collisions are found the causes of radioactive phenomena and in their varying number the cause of isotopy.

The most astonishing feature of the author's theory concerns the linking of atoms: a valence or outer shell electron from each atom takes a coaxial position with respect to the other so that the two valence electrons fall in a straight line connecting the two atom nuclei. The author realizes that the electrostatic repulsion of the electrons would seem to make such an arrangement impossible, but he presents arguments to show that in the equilibrium positions this force would be counterbalanced by attractive forces.

The author complains rather bitterly at the dogmatic manner in which many theorists build on arbitrary assumptions which could never have reality. His own assumptions follow, he claims, naturally and unforced from experimental facts. He gives no details of mathematical analyses to prove his viewpoints although at times he expresses his arguments in mathematical language. It is however not beyond the bounds of possibility that the author has committed the same error he denounces in others. Some of his assumptions seem to be not only arbitrary but unreasonable and a careful reading of his arguments does little to counteract that impression.

The value of a theory of the structure of matter rests in its usefulness in classifying facts of observation and predicting new facts and the more diverse the classes of facts thus brought together the more valuable the theory. The author's unsurpassed acquaintance with such properties of substances as magnetic susceptibility, dielectric constant, frequencies of emitted and absorbed light, etc., place him in a position to measure the serviceability of a theory with respect to such facts.

He likewise offers quite a wealth of chemical fact in support of the adequacy of his theory. Unfortunately, however, very little is first-hand fact of observation. It is rather the conclusion from observation stated in the language of theories of doubtful comprehensiveness. He speaks of valence and changes in valence with assurance, perhaps not realizing that no chemist has ever formulated a satisfactory definition of valence.

The value of this very comprehensive and painstaking work of the author lies in showing the fallacies of some of the current theories and in its suggestiveness as to starting points in building a completely serviceable theory. Some of the baffling physical properties of matter are made in some respects more comprehensible by the author's theory but the chaotic facts of chemistry are by no means brought as nearly into an orderly system by it as by other of the modern theories.

ARTHUR A. BLANCHARD

Vestiges of Pre-Metric Weights and Measures Persisting in Metric-System Europe, 1926-1927. ARTHUR E. KENNELLY, Professor of Electrical Engineering at Harvard University. The Macmillan Co., New York City, 1928. xvi + 189 pp. 9.5 × 14.5 cm. $2.50.

The book is the result of a research with the aid of the Bureau of International Research of Harvard University and Radcliffe College. Professor Kennelly ex-

plains his method of investigation visiting nine different countries.

The author has successfully lifted the subject above the plane of controversy to that of a statistical inquiry which is delightful in contrast to those writers opposed to the Metric System. He barely refers to those who would tell us that "the Metric System is a will-o'-the wisp which the nations of the world are always chasing but never catching," but he gives unimpeachable evidence permitting one to estimate what should occur when a nation adopts the Metric System.

In the first place, a certain interval, usually two or three years, was allowed by law before the change was ordained to go into effect. In the cities and progressive communities the change was made in a few weeks by the bulk of the population. In remote villages and among the less progressive the change occurred more slowly. Similarly, in manufacturing, the change was made more slowly. No machinery was discarded, but the sizes of manufactured articles were numerically altered to conform to the new system. Old drawings were left unchanged until in the course of time they had to be replaced.

Just as the vermiform appendix is a vestigial reminder of the paunch of the ruminants so the apparently arbitrary sizes sometimes suggest systems which antedate the Metric System. Not many people, for example, know the origin of the shoe and collar sizes which they employ. Many of us know that the livre and pfund are used in France and Germany being what Prof. Kennelly calls *Metricised Units*. He says, "Although a constant watch was kept for old standard weights or standard measures in Italy, none but Metric standards were ever found except in museums and antiquity shops." It was much the same over all of Europe visited. In Holland occasionally one asks for an "ell" of something, but no ell stick was found, the ell being made a *sub-metricised unit* of 70 cm. which will before long be unused. The *non-metric unit* of interest is the *Rhineland-inch* used in Germany in measure of boards. The English system appears in the measure of textiles, leather, shoes, and printing but the use is decreasing and often as an arbitrary designation rather than a measure. This result since the war presents a changing condition as regards export trade from this country. Many of the ancient units of Europe exist in name only. Street vendors cry "6 liards the bunch," despite the fact that for a hundred years no one has known what a liard is. The use of the terms liard, livre, and pfund are no more proof that Europe is non-metric than the existence of the Hotel Powhatan is a proof that Washington is inhabited by American Indians.

Rummaging around Europe looking for ancient measures must have afforded much amusement. For example, Professor Kennelly tells us that George Washington was not born on February 22 but on February 11, 1732. The old style calendar was falling hopelessly behind and was therefore moved up eleven days in 1752, which was 170 years after the change had been made by Central and Western Europe.

EUGENE C. BINGHAM

Radicals in Chemistry, Past and Present. MOSES GOMBERG. Columbia University Press, New York City, 1928. 23 pp. 6 × 9 cm. $0.50.

This pamphlet contains the text of the Chandler Lecture delivered December 16, 1927, in Havemeyer Hall, Columbia University by Professor Gomberg, on which occasion the lecturer was awarded the Chandler gold medal for his outstanding work on Tri-valent Carbon and on Free Radicals. It contains a brief but inclusive survey of the history of free radicals, emphasizing chiefly those aspects which are of general interest.

M. W. G.